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THE TREATMENT OF WAR WOUNDS

W. W. KEEN

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The Treatment of War Wounds

By

W. W. Keen, M.D., LL.D.

Emeritus Professor of Surgery
Jefferson Medical College, Philadelphia

✤

Illustrated

Philadelphia and London
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1917

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PREFATORY NOTE

This Report has been much delayed by circumstances beyond my control. Happily the delay has had its compensations, as I have been enabled to add important matter from the large experience of several able surgeons actually in the conflict. I have been enabled also to include the work on Acriflavine, Proflavine and Brilliant Green (p. 162), Mercurophen, and the latest technic on the Paraffin Treatment of Burns, etc., which were not published until recently.

But more especially am I gratified to be able to add, as the Report is passing through the press, two most important contributions to our knowledge—one, the new antiseptic, Dichloramin-T, and the simplified technic of Dakin for the treatment of infection in wounds; and the other the most welcome announcement of an antitoxin against gas gangrene. This will be indeed a boon to many.

I should have quoted Carrel and Dehelly (Le Traitement des Plaies infectées) and Dumas and Carrel (Pratique de l'Irrigation des Plaies dans la Méthode du Docteur Carrel) directly, but unfortu-

nately I was not able to obtain copies of these books until just after I had completed the text. I have, however, been able to utilize some cuts from Carrel and Dehelly by the kind permission of the authors and of Messrs. Masson & Cie, of Paris. I have reproduced some illustrations from the British Medical Journal of June 9, 1917, from a paper by Bowlby. The editor of the Journal gave his permission to use these, but I had to assume that of Sir Anthony, as it was impossible to wait for his permission. I have also to thank Colonel Thomas H. Goodwin, of the British Army, and the Editor of the Journal of the American Medical Association, for permission to use Fig. 2, the diagram from Colonel Goodwin's paper.

WILLIAM W. KEEN

Philadelphia, August 20, 1917.

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THE TREATMENT OF WAR WOUNDS

This Report has been compiled at the request of the National Research Council, and especially of its Medical Committee, of which Dr. Victor C. Vaughan is Chairman. It does not pretend to be complete, but is only a memorandum on some of the more important and most recent improvements in the treatment of war wounds.

Unfortunately, my knowledge is necessarily second-hand, as I have been unable to visit the hospitals in Europe; but the letters from a number of my friends who have had first-hand experience, which I solicited and print herewith, are most valuable documents, covering a number of subjects of importance: some of them medical, besides war wounds proper. My hearty thanks are tendered to them, especially to those who have taken time in their overworked lives to furnish this valuable information. Theirs is indeed first-hand knowledge. In a few pregnant sentences they express convictions which are the result of hard and sometimes bitter experiences of months and even

years of warfare. Even in those letters differences of opinion are seen.

From the surgical point of view, the present war differs widely from any preceding wars in five principal respects:

(1) The huge numbers in the armies and, therefore, of the wounded.

(2) The new means of transportation.

(3) The new weapons, especially in the artillery.

(4) Rampant infection of wounds.

(5) The conquest of infection by more efficient antiseptics and by new methods.

In two additional respects also great progress has been made:

(*a*) The reconstructive surgery of the face and jaws by the coöperation of the dentist and the surgeon, and (*b*) the great development of war orthopedics and the training of disabled soldiers. These two topics I must omit.

I should also call attention to one strange means of preventing wounds, which, though neither surgical nor medical, yet is of great practical value.

We are apparently returning to the use of steel armor, as in the middle ages. Light steel helmets and to some extent corselets over the chest have undoubt-

edly lessened to a very appreciable extent wounds of the head and the thoracic viscera. In trench warfare the head is especially exposed, and here the helmet has found its chief use.

1. The **huge numbers** in the contending armies cause sudden flooding of the hospitals, especially those near the front, with enormous numbers of the wounded after each "drive" or assault. Thus a hospital with 300 or 400 beds may suddenly be overwhelmed by 1000 or more cases.

It is often, therefore, physically impossible to give speedy and thorough treatment to all. A single case, even if it urgently requires attention,—if this will absorb a long time,—may have to wait, for in that same time a dozen others, almost equally exigent, but requiring less time, might be cared for. The greatest good of the greatest number must be the rule. On the other hand, an abdominal case or a case of internal hemorrhage, even if it does involve time, must have precedence of a dozen who can wait. The surgeon's good judgment must be his constant guide.

For the same reason, and for want of the needed aseptic conditions, few abdominal cases and few if any injuries involving the brain should be operated on near the front. Shock from severe wounds and

hemorrhage always must take precedence of everything else.

Porter,* in a graphic and illuminating report on "Shock at the Front," from observations made as perilously near as within 38 meters of the German trenches, has especially called attention to the great saving of life which would result if the same means which have been proved effective in experimental research in animals were adopted in man. His summary of these procedures is as follows:

(1) A special position of the wounded—the abdominal vessels should be higher than the heart and the brain.

(2) Heat.

(3) Intravenous injections of normal saline solution.

(4) Intravenous injections of adrenalin.

(5) The transfusion of blood in certain cases.

(6) The taking of the diastolic pressure every half-hour.

Some of these procedures will require but little time. Even the diastolic pressure, which in severe cases should be recorded at the earliest possible moment, he says can be taken by the auscultatory method in two minutes. The chief drawback is that

* Boston Med. and Surg. Jour., December 14, 1916.

at first it must be taken every half-hour. But the results prove it to be time well spent, for "men who looked like cadavers and were almost pulseless came back to life and after two hours"—requiring only three or four observations, be it noted—"talked pleasantly of their children." A well-trained nurse or an intelligent orderly can attend to some of these details and so free the surgeon.

Bowlby calls attention to the fact that the wounded will often have suffered from loss of blood, loss of sleep, insufficient food, and exposure to cold, and if to these are added severe pain and the exhaustion due to an unavoidable jolting transportation, they will be on the verge of collapse. The first needs of such a man are rest, warmth, and food, of which the first two are the most important. These restoratives may easily be required before any treatment (save for hemorrhage) should be attempted. "The more experienced the surgeon, the less is he likely to hurry on a severe primary amputation." Threatened gas gangrene or rapidly spreading sepsis may force his hand. Much discretion, therefore, must be allowed the surgeon.

Archibald and Maclean* emphasize the need for warmth by stating that in their cases of profound

* Trans. Amer. Surg. Assoc., 1917.

shock the ordinary clinical thermometer did not register low enough, as in some of their cases the temperature was below 92° F. G. Holmes, in injuries of the cord at the sixth to the eighth cervical segments, has observed temperatures of 80° F., yet the patients survived for several days.

2. The **new means of transportation** by automobile has helped enormously. While the wounded must often lie for hours and sometimes days in the "No Man's Land" between the opposing trenches, and the removal of the wounded must be done largely at night, yet, on the whole, often they have been brought to hospitals, as at La Panne to Depage, and at Compiègne to Carrel, within a few hours. Later, attention will be called to the rapidity with which infection spreads, and therefore the overwhelming importance of the earliest possible removal of the wounded to hospitals, where tetanus, gas infection, and other infections can be prevented, ameliorated, or cured.

Hence the means of quick transportation are so important that I have included this as seriously contributing to the proper wound treatment. The diagram on page 18, kindly furnished me by Colonel Henry Page, of the United States Army Medical Service, shows at a glance the scheme of the American army, the different zones of collection, evacuation, distri-

bution; the various kinds of hospitals; the personnel which serves these hospitals, and the means of transportation in each zone. This will save a long description. Compare the diagrams on pages 18 and 19.

It should be noted, as pointed out by Colonel Page, that this plan of charging the Medical Department with the orderly transportation of the wounded from the front, where they were a burden to the fighting forces and where surgical treatment was impossible, to where such treatment was possible, is due to the foresight and administrative ability of Jonathan Letterman, my old Chief and Medical Director of the Army of the Potomac in 1862. He was one of the remarkable military medical men developed by the Civil War.

By the kind permission of Colonel Thomas H. Goodwin, C.M.G., D.S.O., of the Medical Service of the British Army, and of the editor of the Journal of the American Medical Association (July 14, 1917), I am enabled to add a corresponding diagram showing the relation of similar hospitals in the British Army. The average distances, Colonel Goodwin states, are as follows: The "Regimental Medical Officer" will be about 500 yards behind the front trenches, further back, in succession, to the "advanced dressing stations" will be half a mile to a

ZONES OF COLLECTION, EVACUATION, AND DISTRIBUTION IN THE UNITED STATES ARMY

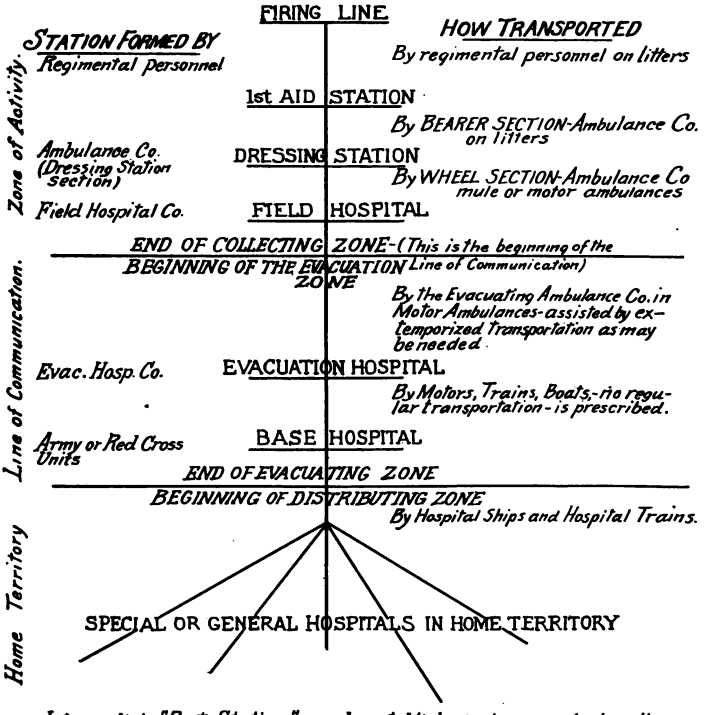

Fig. 1.—Colonel Page's diagram (U. S. Army).

mile, to the "main dressing station" a mile and a half more, and to the "casualty clearing station," say, five miles further.

At [illegible]-aid station, and possibly at the dress-

ing station, only urgent operations should be done, especially, *e. g.*, for the arrest of hemorrhage. No

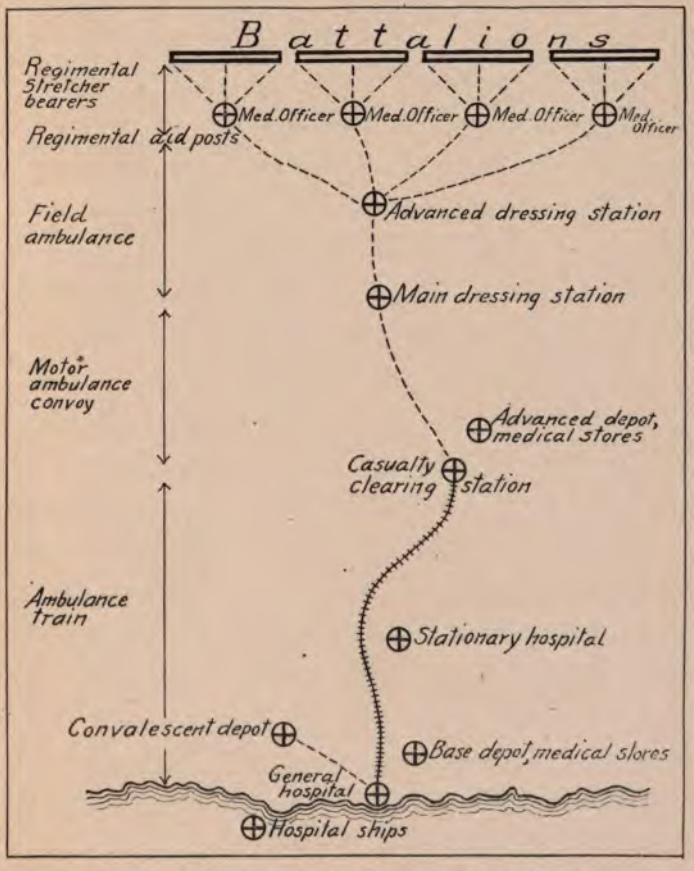

Fig. 2.—Colonel Goodwin's diagram (British Army).

patient should ever be forwarded from there with a tourniquet still applied on a limb. In his admirable

paper on "British Surgery at the Front"* Bowlby advises the amputation of "completely smashed limbs," and the retention of such patients, for at least a day, at what I presume will correspond to our dressing station or our field hospital. Whether this is practicable must be decided by the responsible surgeon in each case, for local and personal conditions vary too much for a hard and fast rule.

His recommendation that abdominal cases and those severe cases requiring such care as cannot be given at this first-aid station should be forwarded to the dressing station ("casualty clearing station" of the British) at once by special motor ambulances, and not be kept waiting for the regular motor convoys leaving at scheduled time, is sound both from the surgical and the humanitarian standpoint. Moreover, as Bowlby points out, had sufficient of these motor ambulances been in use in the early months of the war, they would have saved very many of the wounded from being taken prisoners by the Germans. "The Motor Ambulance," as he forcibly and rightly puts it, "is the very foundation on which all our surgery at the front is based."

This whole article is full of most important matter and should not only be read, but be studied, by every

* Brit. Med. Jour., June 2, 1917, p. 705.

military surgeon. I find it, on the whole, the best summary of the surgical treatment developed by the war which I have read. I shall quote liberally from it.

The *automobile* is indispensable. The American Field Ambulance in France alone has 400 motor ambulances in service, and has transported 300,000 wounded.

Dr. Cabot (p. 138) calls especial attention to the value of interchangeable standardized stretchers. In France an ambulance leaves the patients at the hospital lying on the stretchers, and receives exactly similar empty stretchers with their regular complement of blankets in exchange. This saves time and avoids transferring the patients to hospital stretchers, a process which often causes severe pain and adds to existing shock.

Recently, Dr. Sigmund L. Gans, of Philadelphia, has devised a framework, made chiefly of standard iron pipe, which can be quickly installed on any kind of touring car to carry two patients on regulation stretchers, while five or six sitting and one partly lying patient (on the rear seat) can also be carried if necessary. The cost of this attachment, the Packard Motor Car Company inform me, for a touring car, including the new top, is $50. For cars of smaller size, of course, the cost is considerably less. No alter-

Fig. 3.—Dr. Gans' apparatus for two regulation stretchers and a new top to change a touring car in a short time to an ambulance to carry seven or eight wounded in addition to the chauffeur.

Fig. 4.—The same car fully loaded. The apparatus can be removed and the car restored to its original condition and use in a brief time

ation is needed in the car, and the framework can be removed, restoring the car to its original function in a very short time. The value of such an invention where immense numbers of wounded must be quickly

Fig. 5.—Light railway ambulance trolley (redrawn). (Kindness of the editor of the British Medical Journal and of Sir A. A. Bowlby, Bart. See Prefatory Note.)

moved is evident. The rapidity of the spread of infection hour by hour emphasizes the need of the quickest possible relief.

In what may be called the permanent trench warfare in France a light railway ambulance trolley (Fig.

5),* and even an overhead railway ambulance trolley (Fig. 6)* in the trenches for the rapid transportation of the wounded have been developed. These,

Fig. 6.—Overhead railway ambulance trolley (redrawn). (Kindness of the editor of the British Medical Journal and of Sir A. A. Bowlby, Bart. See Prefatory Note.)

especially the overhead trolley, must be a great boon on account of the much smoother transportation.

The highly organized *hospital trains* in France, over 30 of which are now in operation between the evacuation hospitals (or "evacuating casualty sta-

* Brit. Med. Jour., June 2, 1917, p. 711.

tions," as they are called in England) and the base hospitals, are provided with permanent staffs of surgeons and nurses, with traveling laboratories, *x*-ray rooms, kitchens, and well-equipped operating-rooms. In France hospital barges on the canals, by their smoothness of transit, have been a boon. Well-equipped hospital ships, especially across the Channel, have taken many thousands to permanent base hospitals in Great Britain, where the facilities are equal to the best.

For those with *fractures*, especially fractures of the thigh, Blake's splint provides excellent fixation. Even flesh wounds, especially if large and severe, are greatly benefited by such fixation. All these better means of speedy and more comfortable transportation contribute greatly to recovery.* Cabot and Cushing emphasize this fact. (See their letters, pp. 133, 144.)

Chase gives a useful little hint as to plaster, viz.: Just before the cast is dry it may be coated with talcum powder well rubbed in. This makes a smooth surface, which can be washed, and on it the date and other memoranda may be written.

* Lord Northcliffe's interesting account of a "Visit to the Front" is reprinted from the London Times of October 4, 1916, in the Military Surgeon for December, 1916.

The "Balkan splint" is simple, useful, and widely employed in hospitals, but it is not adapted for transportation. The Thomas and other similar splints have been much used by the British.

Crile insists rightly upon the value of morphin for

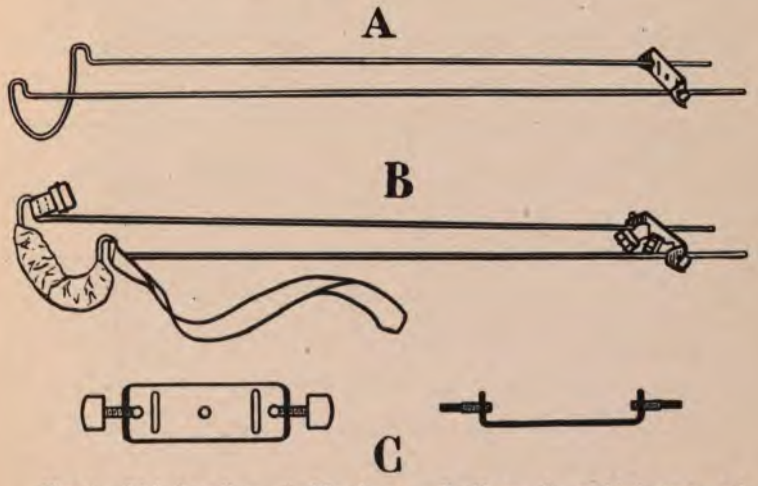

Fig. 7.—Blake's splint: A, The frame. B, Shows the padded strap and buckle to encircle the thigh. C, Details of the foot-piece. On this the slits for the buckles should be 105 to 110 mm. apart. (Courtesy of Dr. Joseph A. Blake.)

men suffering severely, whether in hospitals or during transportation. After the second Bull Run, when a train of over 100 ambulances carrying the wounded to Washington, after they had been lying for three days uncared for and undressed, halted in the night at Centreville, I found the two most needed things

were water and morphin. On the other hand, too much morphin is as bad as too little, especially in abdominal cases.

3. **New weapons** have caused a new type of wounds. At first there were many bullet wounds,

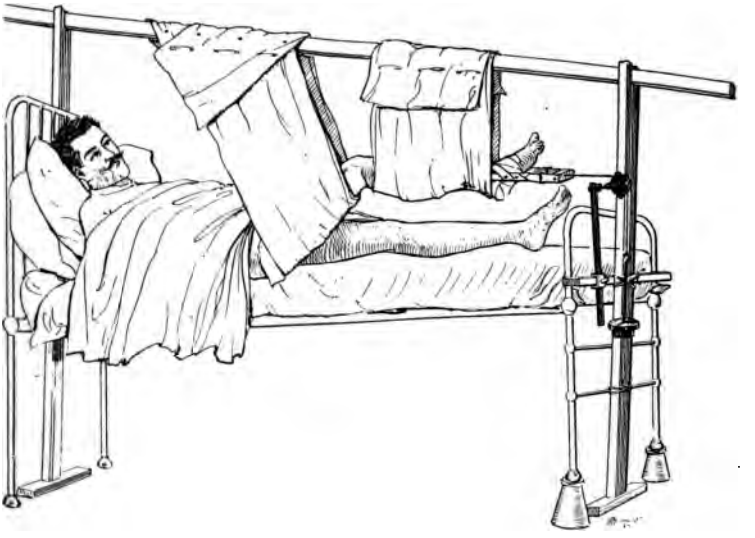

Fig. 8.—Balkan splint as used at the American Ambulance, Neuilly-sur-Seine, Paris, France. (Crile, in Annals of Surgery, July, 1915. Attributed to Lt. Col. Miles by Sir Geo. H. Makins, Brit. Med. Jour., June 16, 1917.)

then shrapnel wounds outnumbered those caused by the rifle, and now the high explosive shell is the chief weapon. Artillery has leaped into new and dominating importance. These shells, all surgeons agree, produce terrible and wide-spread mutilations. Frag-

ments of the shells not only may lodge, but also in most cases carry deep into the tissues, in the majority of wounds, bits of dirty clothing, skin, and other foreign bodies, all heavily infected. Diligent search must be made for such foci of infection at the very first opportunity for a thorough dressing, or deep and wide-spread infection is sure to follow.

It must not be forgotten that these modern bullets and fragments of high explosive shells produce grave destruction of tissue not merely in the track of the missile, but that the tissues at varying distances all around and beyond the wounds are devitalized. This destruction is often not recognizable by the eye or touch until some time has passed. Bowlby, quoted by Moynihan,* has shown that a kidney wounded in its lower pole presented to the naked eye a normal appearance at its upper end, but the microscope showed that the tubules in that part were disorganized.

This wide-spread devitalizing of the tissues has led to the common-sense practice, especially urged by Carrel, after primary disinfection, of excision of the tissues surrounding the wound itself instead of allowing them to slough off and serve as an excellent nidus for infection. Shells and shrapnel also frequently cause multiple wounds. The fragments of a shattered

* Brit. Med. Jour., March 4, 1916.

bone act as additional secondary projectiles and further enlarge the area of destruction.

Chase* says that "multiple wounds are the rule. . . . Thirty, forty, or fifty wounds from the explosion of a shell close by are not particularly rare." He then describes one stretcher-bearer who had "well over one hundred wounds. We picked out pieces of shell, newspaper, clothing, and gravel for days afterward." Fortunately, no one of the wounds was serious, and in the course of a month he was ready for furlough.

All these complicating conditions complicate also the treatment. But the chief outstanding fact is virulent and all-pervading infection.

The soil of Belgium and France has been cultivated for over twenty centuries, since even before the days of Cæsar's Gallic War. The fields have been roamed over by cattle, horses, swine, and other animals, including man himself; the soil has been manured thousands of times, and so is deeply and thoroughly impregnated with fecal bacteria in addition to the ordinary pyogenic bacteria.

The soldiers have lived in trenches for months, begrimed and bedaubed with mud, without suitable facilities for bathing and change of under and outer

*Annals of Surgery, July, 1917.

clothing, especially in the early days of the war. It was not uncommon at that period for a man to be unable to change even his trousers for weeks. When, therefore, a missile carried into the wound a piece of dirty, mud-impregnated skin, coat, trousers, underclothing or socks, or when a large lacerated wound was in contact with the long-soiled clothing, and the wounded man would perhaps lie on the ground uncared for for hours or days, it was no wonder that violent infection from pyogenic organisms and the bacteria of tetanus and gas gangrene ran riot.

Carrel* has observed that when a wound was examined bacteriologically as early as six hours after it had been inflicted there was found a varied flora of both aërobic and anaërobic bacteria, but that they were few in number, and localized chiefly around the missile or a bit of clothing, etc., without as yet spreading far and wide into the tissues. Twenty-four hours later, however, the bacteria were found everywhere, and were too numerous to count. Moreover, as Wright has pointed out, when there has been delay in dressing a wound, the dried blood sealing the wound creates an almost ideal condition for the growth of the deadly anaërobic bacteria of tetanus and gas

* Bull. Acad. Méd., lxxiv, No. 40, and Brit. Med. Jour., Oct. 23, 1915.

gangrene. (*Vide infra*, Tissier's observation, p. 90.) It is no wonder then that experience has shown that excision of this damaged and heavily infected tissue is one of the prime factors in the treatment of the badly wounded.

Bowlby (*loc. cit.*) points out that "if a badly wounded man cannot be rescued and brought into the field ambulance until after the lapse of twenty-four or thirty-six hours, the wound is often already so badly infected and the patient himself is in so toxic a state that surgical treatment has but little chance. It may be said truly that the most important alteration in treatment since the early days of the war is that excision of damaged tissue has become the routine method, and that the earlier it is carried out, the more likely it is to be successful."

Could there possibly be stronger reasons for urging that every wounded man, if it is at all possible, should obtain thorough care during the very first golden hours, when efficient treatment would save his life? Military conditions may, and too often do prevent this early dressing, but this, above all other factors for recovery, should be the aim both of the surgeon and the commander, for so human lives are saved and armies are less depleted by death and disability.

In the navy, on the contrary, where the factor of

infected soil was not present, "sailors with the most severe type of wounds, ragged, irregular, with uneven surface, produced by herniated muscles and retracted, severed fibers, usually recovered quickly."*

Moreover, in the terrible but magnificent retreat from the Aisne to the Marne, many and in some cases almost every man was exhausted to the last degree mentally as well as physically. Crile† has given a wonderful picture of the exhaustion of these patients, who practically slept while they marched, who slept through painful dressings or even operations. The nervous strain to which the men are subjected in the trenches impairs greatly their ability to withstand the almost malignant infection which invades the great gaping wounds.

Early experiences in the war demonstrated the fact that both antisepsis and asepsis as heretofore practised had been vanquished by Mars. Each was tried and each failed. It was even proclaimed that Lister's work went for naught. Now, however, antisepsis and asepsis (in its proper place) have come into their own again, and Lister is still the apostle of good tidings. The reasons are plain. First, we did not then possess sufficiently effective antiseptics, such as modern

* Jour. Amer. Med. Assoc., May 22, 1915, p. 1765.

† Mechanistic View of War and Peace, Macmillan, 1916.

research has now given us: second, we were not masters of an effective and successful technic. We owe these especially to two men—Dakin and Carrel—who have wrought a marvelous revolution.

Lister taught us, above all, how to *prevent* infection; Dakin and Carrel, following Lister's principles, have taught us how to *conquer* even rampant infection. For nearly half a century surgeons have been fighting firmly entrenched infection, but always in vain. It required the stern stimulus of war to enable us to win the victory. Prevention and cure both are now ours.

Two still newer antiseptics with apparently quite remarkable bactericidal qualities have been recently discovered - too recently, I think, as yet for them to have had the test of a large experience, as they ought surely both to have.

The first is designated by the short name "*flavine*," instead of the long chemical name. A full account of this, with the process of manufacture, is given by Browning and his colleagues fom the Bland-Sutton Institute of Pathology of the Middlesex Hospital, London, in the British Medical Journal for January 20, 1917, p. 73.

For technical reasons "flavine," as one of the "acridin" series, is now called "*acriflavine*." A still

more potent preparation is foreshadowed and is to be called "proflavine."*

Dakin, in the same journal for June 23d, indorses Browning's statements as to acriflavine. Its antiseptic action, instead of being diminished by blood-serum, is increased even up to five times its potency in water. Moreover, as Browning showed, it is harmless to the tissues and even to the activity of the leukocytes (phagocytosis).

The second one, which is still more recent, is announced in an important paper by Schamberg, Kolmer, and Raiziss, on a "Mercurial Germicide," which they have named "Mercurophen," in the Journal of the American Medical Association for May 19, 1917, p. 1458.

Mercurophen apparently does not corrode metal instruments. It is said to be non-irritating, yet to be a far more powerful germicide than corrosive sublimate, carbolic acid, etc., and therefore excellent for sterilizing the hands. Though so effective a germicide, it is non-poisonous. Dr. Walter J. Freeman has used it for some time in his laryngologic work as freely as he would a boric-acid solution and commends it highly. Several of my surgical and ophthalmologic friends are well satisfied with the

* Brit. Med. Jour., June 9, 1917.

clinical results, in the moderate number of cases in which they have been able to try it, in the short time since it has been available. That it has been used as a preoperative disinfectant for the eye, and that sutures have been left in place for three or four weeks without causing any irritation, speak well for its not being harmful to the delicate cells of the cornea and conjunctiva, nor to the tissue cells of a wound.

Several new methods of treating infection have been proposed. Each has had its warm advocates and each has been assaulted sometimes with more or less acerbity. A number of these are referred to in an admirable series of articles on Surgery in the British Navy,* together with an assessment of their relative values.

Personally, I have seen none of them used. I can judge only by the published results. "By their fruits ye shall know them." Judging by this standard, I can only conclude that one method—that of Carrel and Dakin—has shown results so much superior to the others that I shall restrict myself to this method alone in detail. If I am asked to give the reason, I need only quote the following paragraph, describing what Dr. C. L. Gibson, of New York,† saw at La

* Brit. Med. Jour., April 28, 1917, p. 533.

† General Bulletin, Society of the New York Hospital March 27, 1917.

Panne, Belgium, where the method is strictly and efficiently carried out.

"Dr. Depage greeted me by saying that he had 80 compound fractures all grouped in one ward and that not one was suppurating. He kindly devoted a whole forenoon to their demonstration, and I had an opportunity to see every one of these 80 cases, even to the smallest details. None of the dressings were touched till I had an opportunity to see them and estimate the amount and nature of the discharge contained on them. I had an opportunity also to see the bacterial chart of every one of these cases, see a number of these cases 'closed,' and in some cases observe their condition and final healing. I was able not only to corroborate Dr. Depage's statement that not one of these compound fractures was suppurating, but could affirm, in addition, that I failed to see a single drop of pus in any one of these cases. When one remembers that these wounds offer the maximum possibilities, particularly the shell wounds, with terrific mangling of the tissues, extensive splintering of bone, harboring many and diverse forms of projectiles and foreign bodies, necessarily all primarily infected,—in other words, the worst possible imaginable wounds,—the result is something one must know for oneself to appreciate.

"These wounds heal in a manner that is simply indescribable. One has to see the behavior of these sutured wounds oneself to realize what happens. They

heal with no more reaction from their appearance and manifestations than would be given by a wound which has been sutured on a cadaver—total absence of reaction, pain, swelling, redness, and even of infiltration around the wound edges. Dr. Dehelly, of Havre, tells me that he has closed 400 of these wounds with only six failures to obtain perfect primary union. Of these six mishaps, none was of any importance, and in some of these Dehelly said the fault was probably due to his failure to await complete sterilization, as evidenced by the bacterial count."

I have never yet seen any report of 80 cases of compound fracture of the thigh without a drop of pus when treated by any other method. When myself in active practice, I should have been more than gratified had I realized such a result, even in the best of conditions and in civil life, where infection is far more easily dealt with.

Tuffier alleges that 80 per cent. of all amputations are due to infection. If we can now conquer infection, most of these mutilations will probably be avoided.

What an immense boon this will be to the soldiers, and therefore to the community, by enabling them, even if only partly, to earn their daily bread, is most evident. The military commanders will be equally gratified by the return to their commands of many of the wounded who otherwise would have been

returned to civil life in this mutilated condition or have been carried to the cemetery.

It is but fair to state that independently in the British Medical Journal, July 24, 1915, p. 129, Lorrain Smith, Drennan, Rettie, and Campbell, of the Department of Pathology in the University of Edinburgh, published their "Experimental Observations on the Antiseptic Action of Hypochlorous Acid and its Application to Wound Treatment." They devised two forms of its use—a powder which they named *Eupad*, and a solution which they named *Eusol*. Eupad consisted of equal weights of finely ground bleaching powder (chlorid of lime) and of boric acid. Eusol was standardized at 0.5 per cent. of hypochlorous acid. Both of these preparations have been much used with good results, but, on the whole, they do not seem to have been so satisfactory or at least have not gained the same wide-spread repute as Dakin's fluid.

Hypochlorous solution has been produced from hypertonic saline by Beattie, Lewis, and Gee,* and is claimed by them to have certain advantages over other similar preparations.

* Brit. Med. Jour., February 24, 1917, p. 256.

THE DAKIN-CARREL METHOD

The Dakin-Carrel method consists in the use of Dakin's fluid of sodium hypochlorite in a solution of 0.5 per cent. strength, with a special technic devised by Carrel. The method requires special training. To provide this training the Rockefeller Foundation is now erecting a special temporary hospital on the grounds of the Rockefeller Institute in New York, and will have the personal services of Dakin and Carrel for the instruction of surgeons in the military service of the country. Much of the adverse criticism has seemed to come from those who have not had the advantage of instruction by Carrel at Compiègne or by Depage at La Panne. Depage personally visited Compiègne and there became familiar with the details of the method. Those who have visited Carrel's and Depage's hospitals have come away enthusiastic in praise of the results there attained. The results, they aver, are simply wonderful.

Dakin's Fluid.—While in this country, Dr. Dakin has been kind enough to give me the following formulas of the fluid—one with and the other without

boric acid. The latter seems to have given the best results in the hands of those who have tested both.

Preparation of the Dakin Solutions.—"Neutral hypochlorite prepared with boric acid is best made as follows: One hundred and forty grams of dry sodium carbonate (NaCO), or 400 grams of the crystallized salt (washing soda), are dissolved in 12 liters of tap-water, and 200 grams of chlorid of lime (chlorinated lime) of good quality are added. The mixture is well shaken, and, after half an hour, the clear liquid is siphoned off from the precipitate of calcium carbonate and filtered through a plug of cotton; 40 grams of boric acid are added to the clear filtrate, and the resulting solution is ready for use. A slight additional precipitate of calcium salts may slowly occur, but it is of no significance. The solution should not be kept longer than one week. *The boric acid must not be added to the mixture before filtering, but afterward.* The solution should be tested for neutrality by adding some of it to a pinch of solid phenolphthalein. If a red color, indicating free alkali, should develop, a little more boric acid must be added in order to remove it."

Daufresne's Technic.—"Neutral hypochlorite prepared without boric acid is best made according to the formula given by Daufresne, and at the present time is perhaps more generally used than any of the other modifications.

"Two hundred grams of good bleaching powder are

put in a 12-liter bottle with five liters of tap-water. The solution is shaken vigorously and allowed to stand for at least six hours, unless a mechanical shaker is used, when half an hour's shaking will be found sufficient. In another vessel 100 grams of dry sodium carbonate and 80 grams of sodium bicarbonate are dissolved in five liters of cold water and then added to the bleaching powder mixture. The whole is shaken vigorously for a few minutes, and the precipitate allowed to settle. At the end of half an hour the clear solution is siphoned out and then filtered through paper. The proportions given above for the carbonate and bicarbonate of soda are those given by Daufresne. It is our experience, however, that with most brands of American bleaching powder it is better to use 90 grams of each salt. This solution must invariably be tested for neutrality by adding a pinch of solid phenolphthalein to a little of the solution. If the solution should react alkaline, one of three methods must be employed to correct it, otherwise skin irritation will surely result.

"(*a*) Pass carbon dioxid gas into the solution until a sample shows no alkalinity when tested as described. This is perhaps the best method.

"(*b*) A neutral hypochlorite may be secured by reducing the proportion of carbonate of soda and increasing the bicarbonate.

"(*c*) Boric acid may be added until neutrality is secured.

"An advantage of the carbonate-bicarbonate prepa-

ration is that it possesses greater stability and can be kept for several weeks without much deterioration. On the other hand, with varying qualities of bleaching powder, containing different amounts of free lime, it is more difficult to adjust the proportions so as to obtain a neutral solution directly. Probably those having adequate laboratory facilities will prefer the carbonate-bicarbonate solution, while the mixture containing boric acid is readily made under less favorable circumstances."

In addition to this I add some further details from Dr. H. H. M. Lyle's excellent paper.*

The fluid is "an ideal isotonic wound antiseptic of high bacterial and low toxic or irritating quality," in which it differs from the old familiar Labarraque's solution. It does not injure the living tissues.

Lyle adds the following note as to Daufresne's technic: "The solution of sodium hypochlorite for surgical use must be free from caustic alkali; it must contain only from 0.45 to 0.50 per cent. of hypochlorite. Under 0.45 per cent. it is not active enough, and above 0.5 per cent. it is irritant." At 50 per cent. the skin around the wound must be protected by yellow (not white) vaselin.

"*Test for Alkalinity.*—As the commercial chlorin-

* Jour. Amer. Med. Assoc., January 13, 1917.

ated limes are of inconstant strength, the solution should always be tested. Pour 20 c.c. of the solution into a glass, and drop on the surface of the liquid a few centigrams of powdered phenolphthalein. Agitate the fluid by giving the glass a circular motion, as if one were rinsing the glass. The liquid ought to remain colorless. A red tint more or less intense indicates the presence of a quantity of free alkali or an incomplete carbonation due to faults in the technic.

"*Titration of the Solution.*—Measure 10 c.c. of the solution; add 20 c.c. of 1:10 iodin solution and 20 c.c. of acetic acid. Pour into this mixture a decinormal solution (2.48 per cent.) of sodium thiosulphate (hyposulphite) until decoloration.

"Let N equal the number of cubic centimeters of thiosulphate employed. Then the quantity of sodium hypochlorite for 100 c.c. of the solution would be given by the equation:

$$T = N \times 0.03725.$$

"*Precautions: Never heat the solution!* If, in case of an emergency, it is necessary to titrate the chlorinated lime, use only water, never with the solution of soda salts.

"*Titration of Chlorinated Lime* (*Bleaching Powder*).—The variation in the strength of the commercial products makes it necessary to determine the amount of active chlorin in the bleaching powder. The first step is to obtain an average sample. This is done by selecting small amounts of the bleaching powder from

"QUANTITIES OF INGREDIENTS REQUIRED TO OBTAIN 10 LITERS OF 0.5 PER CENT. HYPOCHLORITE SOLUTION

Titration of Chlorinated Lime (Cl)	Ingredients		
	Chlorinated Lime	Sodium Carbonate	Sodium Bicarbonate
Per Cent.	Gm.	Gm.	Gm.
20	250	125	100
21	240	120	96
22	230	115	93
23	220	110	88
24	210	105	84
25	200	100	80
26	190	95	76
27	180	90	72
28	175	87	70
29	170	85	68
30	165	82	66
31	160	80	65
32	155	78	62
33	151	75	60
34	147	73	59
35	143	71	57

different parts of the jar. Weigh 20 gm. of the selected powder and mix it with one liter of water. Allow it to remain in contact for a few hours; then take 10 c.c. of the clear fluid, add to it 20 c.c. of a 10 per cent. solution of potassium iodid and 2 c.c. of acetic or hydrochloric acid. To the resultant solution add a decinormal solution of sodium thiosulphate (2.48 per cent.) until decoloration. The number N of cubic centimeters of thiosulphate employed, multiplied by 1.775, will give the weight N of active

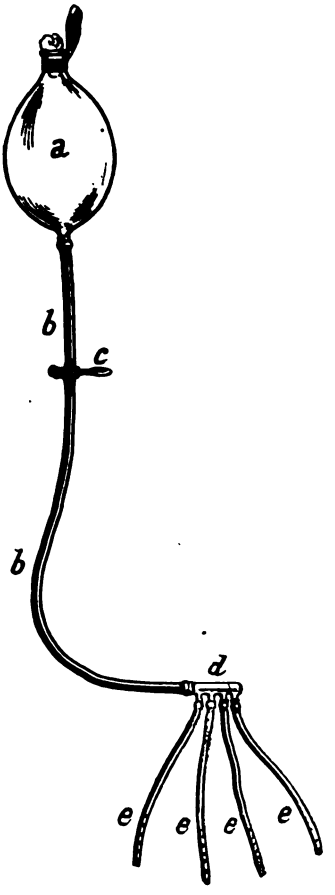

Fig. 9.—Carrel's irrigation apparatus: *a*, Reservoir for Dakin's fluid; *b*, the main distributing tube; *c*, the metal pinch-cock; *d*, glass tube with multiple openings; *e*, *e*, *e*, *e*, final distributing tubes closed at distal end, but perforated with openi[illegible] mm. each (Carrel and

chlorin contained in 100 gm. of chlorinated lime. The test is applied to every new sample of bleaching powder. If the sample contains more than 25 per cent. of active chlorin, the proportion of the three chemicals in the formula must be decreased; and if it is less than 25 per cent., it must be increased. That is, each of the three numbers—200, 100, and 80—are multiplied by 25/N, N representing the weight of the active chlorin per cent. of the bleaching powder.

"*Necessary Materials.*—1. A solution of 0.5 per cent. sodium hypochlorite prepared by the Dakin and Daufresne technic.

"2. A glass container with a capacity of from 500 to 1000 c.c. (Fig. 9, *a*).

"3. Two yards of moderate-sized rubber tubing.

"4. An adjustable clamp for controlling the flow of the solution (Fig. 9, *c*).

"5. Rubber instillation tubes about 25 cm. long, with assorted diameters (average size, No. 16 French). These tubes are tied at the extremity and perforated

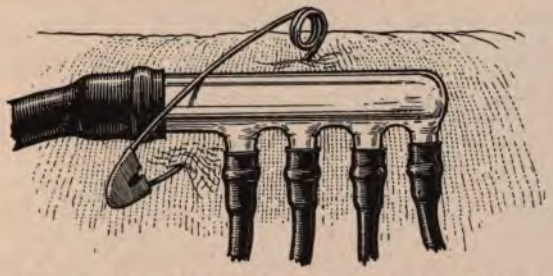

Fig. 10.—Showing Carrel's glass tube (Fig. 9, *d*) to connect the main distributing tube (Fig. 9, *b*) from the reservoir to multiple final small distributing tubes (Carrel and Dehelly).

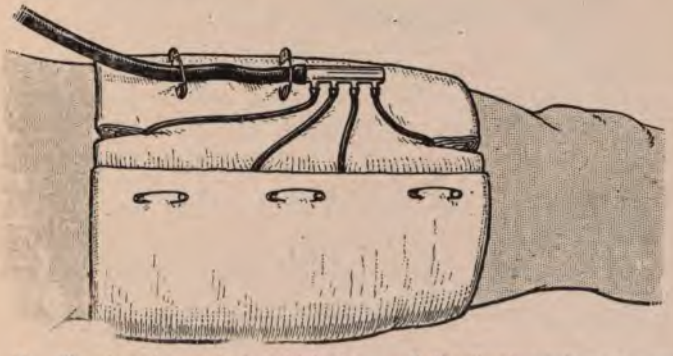

Fig. 11.—Showing the mode in which the small distributing tubes are carried through the dressing to the various parts of the wound (Carrel and Dehelly).

with holes made with a punch. The primary and secondary tubes are 7 mm. in internal diameter, the final distributing tubes 4 mm., and the little holes in these tubes are only 1 mm. ($\frac{1}{25}$ inch) in diameter.

[illegible] rubber tube drains, from 25 to 35 [illegible] without lateral holes.

[illegible] and distributing tubes (Fig. [illegible]

The dressings consist of cotton surrounded by [illegible] The cotton consists of a layer of absorbent [illegible] with a thicker layer of non-absorbent cotton. These dressings are about 3 cm. thick, and of different sizes. Three different sizes are sufficient—one large enough to surround the leg once, a second to surround

Fig. [illegible] showing a similar distribution as in Fig. 11, by means of a Y-tube, thus [illegible] the number of final distributing tubes (Carrel and Dehelly).

the arm, the third still smaller. Webbing straps with buckles to fasten the dressing in place.

"9. Sterilized pieces of gauze impregnated with yellow petrolatum to be used in the protection of the skin.

"**Operative Technic to Prepare the Wound for the Introduction of the Antiseptic.**—The future course of the wound is directly dependent on the thoroughness of the first surgical act. This should be carried out under the strictest aseptic precaution and at the earliest possible moment. It consists of a thorough,

methodical, mechanical disinfection of the wound, with the extraction of all shell fragments, particles of clothing, dirt, etc. [For the new stereo-fluoroscopic method of extracting foreign bodies, see p. 68.]

"The operative field is painted with tincture of iodin, and the bruised and necrotic skin-edges of the wound are trimmed away with a sharp knife. The knife and forceps are then put aside. With new instruments the wound is laid open like a book and gently explored for shell fragments, pieces of clothing, pockets, etc. Everything that could have been infected by the traumatism or could become the source

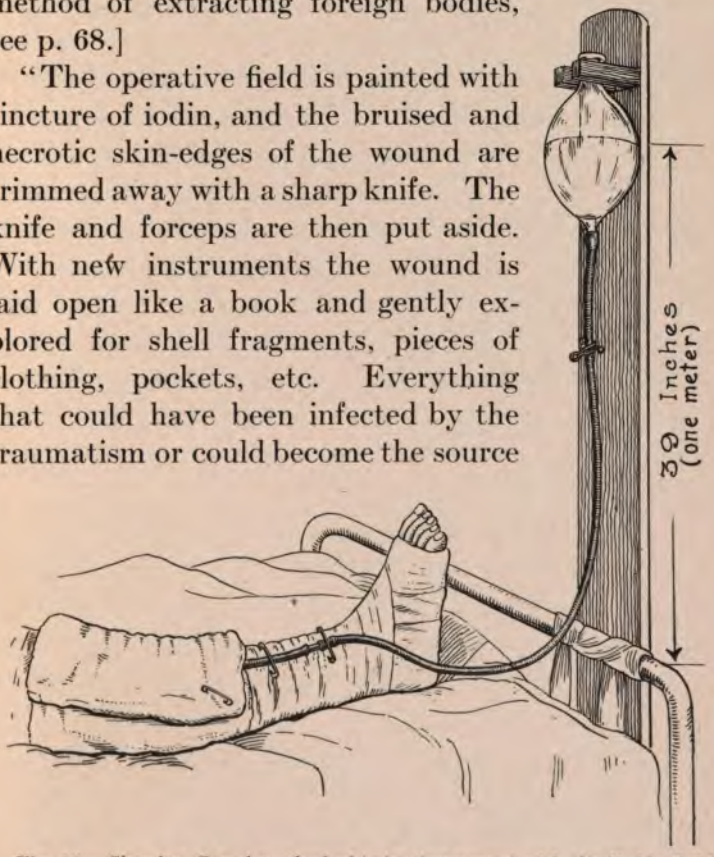

Fig. 13.—Showing Carrel method of irrigating wound with the Dakin fluid. Note on the main distributing tube the pinch-cock below the reservoir. The wound is covered with the dressing, which is fastened by safety-pins. The distributing tube is similarly held in place by being pinned to the plaster cast (Carrel and Dehelly modified).

of infection is removed. All non-infected tissues and tissues unlikely to become infected are preserved.

"Gentleness of manipulation is the keystone of the technic. Brutalization of the traumatized tissue is a technical crime. In many of the cases it will be found that fibers of clothing, dirt, grass, etc., are encrusted in the muscular surfaces of the wounds. To avoid overlooking this blood-stained débris the track of the projectile must be lightly but methodically resected. Great conservatism is exercised in the removal of comminuted fragments of bone. The same minute and careful mechanical cleansing is carried out in osseous wounds as in the soft parts. Before placing the instillation tubes, a careful revision of the wound is made, and particular attention paid to securing a perfect hemostasis. Muscular tissue infiltrated with blood is difficult to disinfect.

"There is another reason special to the employment of Dakin's solution which calls for a thorough hemostasis. Owing to its hemolytic property, Dakin's solution has the power of dissolving recent blood-clots. A poor hemostasis invites the danger of a secondary hemorrhage.

"Counter-openings for drainage are rarely employed. If the necessity for their use should arise, one should avoid making them at the most dependent point, as the goal of technic is to keep the liquid in contact with *all* the surfaces of the wound.

"**The Introduction of the Instillation Tubes.**—The guiding principle to place the tubes so that the

liquid will come into contact with every portion of the wound. The placing of the tubes will vary with the nature of the wound.

"*Superficial Wounds.*—A thin layer of gauze is placed over the wound, and on this the requisite number of instillation tubes. The tubes are secured to the wound-edges by a rubber cuff and suture or a two-way-flow tube is used. If the tubes are placed directly on the surface, they become encrusted and the orifices are blocked with granulations. Too thick a layer of gauze should not be used, as it will become clogged with the wound secretions and prevent the solution from reaching the wound.

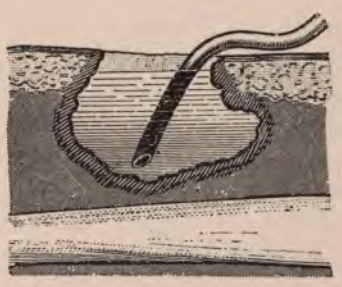

Fig. 14.—Showing Carrel's method of using Dakin's solution in an anterior wound and keeping the wound full of the solution so as constantly to attack the infecting bacteria (Carrel and Dehelly).

"*Penetrating Wounds.*—In the simple type, a tube without lateral perforations is introduced to the depth of the cavity and the solution allowed to well up from the bottom (Fig. 14). In a large tract terminating in a cavity with irregular collapsible walls a little gauze is introduced to support the walls of the cavity and allow a more thorough distribution of the fluid. Penetrating wounds with the point of entrance in a dependent position (as the buttock, posterior surface of the extremities, and the back) are treated with per-

forated tubes dressed with toweling (Fig. 16). These dressed tubes keep the antiseptic in contact with the wound. A suitable non-perforated tube can also be used.

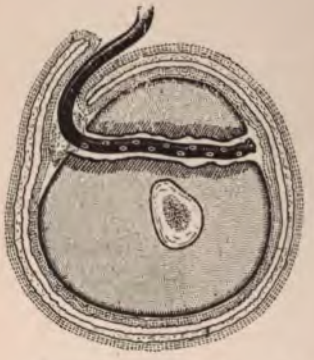

Fig. 15.—Showing the method by which the distributing tube enters the wound through the dressing without being constricted (Carrel and Dehelly).

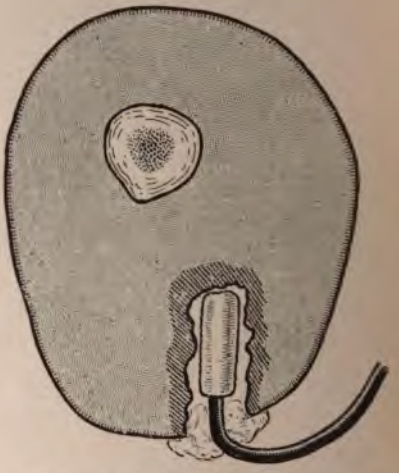

Fig. 16.—Mode of irrigating a wound in a posterior position. Observe that the distributing tube is here necessarily surrounded with toweling, otherwise the fluid would escape almost immediately. This toweling should be firmly sewed to the distributing tube by silk and not by catgut, so that it may not become detached and be left in the wound (Carrel and Dehelly).

"*Through-and-through Wounds.*—A perforated tube with the tied extremity uppermost is passed from the lower to the upper wound. The liquid, escaping through the small lateral holes, flows back along the ·t to the inferior orifice, moistening the entire ·l.

"Wounds of the hand or foot, open amputation stumps, etc., are immersed in Dakin's solution for from ten to fifteen minutes every two hours until the wound is sterilized. The skin is protected by smearing it with sterile yellow petrolatum.

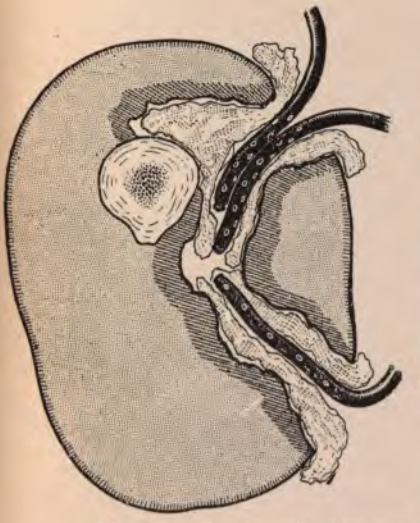

Fig. 17.—Showing the *improper* way of placing the distributing tubes. They are in contact with the gauze instead of in contact with the wound (Carrel and Dehelly).

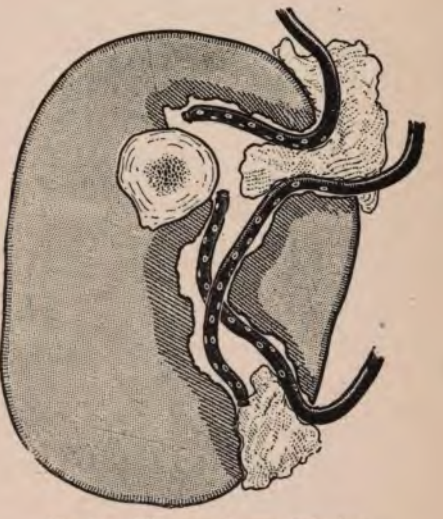

Fig. 18.—The *correct* way of placing the distributing tubes so that the Dakin fluid comes directly in contact with all the surfaces of the wound (Carrel and Dehelly).

"**The After-care of the Wounds.**—The materials used are described above. In the care of the wounds a strict instrumental technic is employed, the gloved hands never coming in contact with the wounds or dressings.

"Instillations of the fluid are made every two hours [day and night] by releasing the adjustable clamp [for a second or two] (Fig. 12) controlling the flow. The amount of solution employed varies with the nature and extent of the wound; for the average wound, 10 c.c. are sufficient. This interrupted instillation is kept up until the wound is proved sterile. The tubes are then removed, and a compress moistened with Dakin's solution is applied. Formerly a continuous instillation was the method of choice: if used at all, it should be discontinued in from twenty-four to forty-eight hours. The rate of instillation is from 5 to 20 drops a minute, according to conditions. The object is to moisten the wound surfaces and not flood the bed.

"Once a day—oftener, if necessary—the wound, the tubes, and the flow of the liquid are inspected. Flushing the wound shows if the solution is being delivered as planned, and mechanically washes away the excess of wound secretion.

"The Carrel method is not a continuous irrigation. It is a mechanical attempt to deliver an antiseptic of definite chemical concentration to every portion of a surgically prepared wound and to insure its constant contact for a prolonged period. . . . . .

"**Systematic Bacteriologic Examination of the Wound.**—This consists in a regular determination of the number of microbes on the wound surfaces. This is done by transferring with a standard loop a portion

retion to a slide and counting the number of

microbes per microscopic field. This is carried out every second day, and the results are entered on a suitable chart. When the microbes are absent from the wound on three successive counts, the wound is considered sterile. Though not absolute, the bacteriologic control is of great practical value as a therapeutic guide. . . . . .

"It is better to begin the bacterial chart one or two days after the reception of the patient. As a rule, the germs begin to appear after the ninth or tenth hour. There is an initial rise on the second or third day. This remains so for a few days, and then the descent begins. Wounds on the soft parts are sterilized in from five to eight days. Greatly traumatized wounds require a longer time. Fractures can be sterilized in from two to four weeks. If sequestra are present, they must be removed to obtain an asepsis.

"Wounds sterilized by the Carrel method are readily reinfected if the treatment is stopped.

"**Reunion of Wound.**—When, by three successive tests, the bacteriologic examination shows the wound to be sterile, it is closed by careful layer sutures. In the favorable cases this can be done on the fifth day. The average time for the soft parts is from seven to nine days.

"In cases in which sutures cannot be employed the wounds are closed by adhesive straps passed in such a way that, besides pulling the edges of the wound together, they make a compression around the whole circumference of the limb, or a 'corset lacing' (Fig.

19). Care must be taken not to have the circular bandage, if this be used, too tight.

"For extensive wounds two Canton-flannel bands are prepared, the length to be slightly longer than the wound, the breadth to be a little less than half the circumference of the limb. On the hemmed edges shoe-hooks are inserted every 2 cm. The limbs are painted up to the edges of the wound with a resin

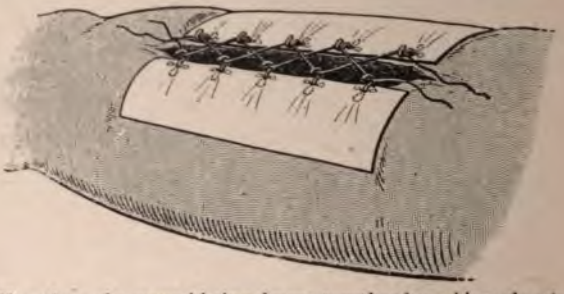

Fig. 19.—The edges of a wound being drawn together by rubber elastic traction. (Carrel and Dehelly).

varnish or Heusner's glue (see page 160), and the woolly side of the Canton flannel applied. One should wait until the traction strips are firmly adherent before lacing them with rubber bands. The tension of the rubber bands rapidly draws the wound edges together."

In the entire treatment of these wounds even the gloved hands never are allowed to touch any dressing or the wound. Everything is handled by forceps, [illegible]n be so much more certainly disinfected than [illegible] even gloves.

When a wound has filled up and is in condition to cicatrize, Carrel and Count du Noüy, a French physicist, by means of a "planimeter," are able to measure the exact area, *i. e.*, the number of square centimeters,

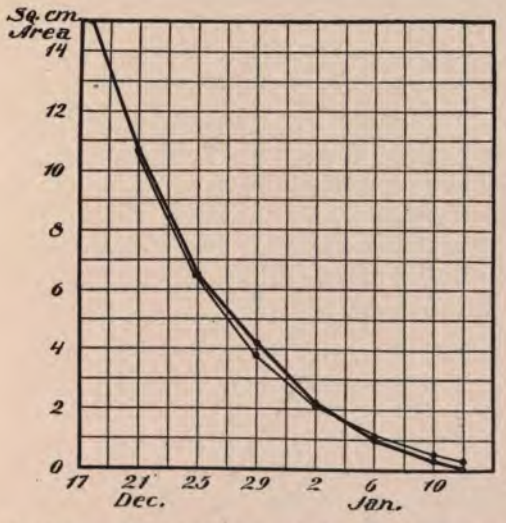

Fig. 20.—On December 17th the area of the wound was 16.2 sq. cm. A slight infection between December 27th and 29th, when one microörganism in two microscopic fields was found, caused a slight deviation of the actual curve from the calculated curve. (Kindness of Carrel and du Noüy and the Jour. Exp. Med., 1916, xxiv, 454.)

in the most irregular wound. The number of square centimeters is entered on a chart (Figs. 20, 21, 22, vertical numbers) every second day. The dates are entered according to the horizontal numbers. After three or four observations have been entered, a "curve

of healing" is established. By prolonging this curve they can predict with almost absolute accuracy the

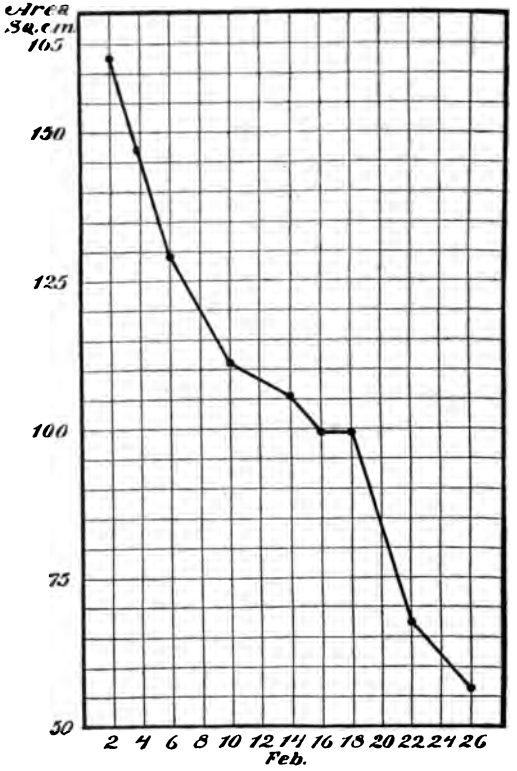

Fig. 21.—Wound of the abdominal wall. The horizontal part of the curve from February 16th to 18th represents a period of slight infection. As soon as the wound was sterilized chemically the curve descended abruptly. (Kindness of Carrel and Hartman and the Jour. Exp. Med., 1916, xxiv, p. 437.)

day on which a given wound will be completely healed. It is remarkable how nearly the "actual"

curve and the "calculated" curve in a normal case coincide (Fig. 20). Any renewed infection, of course, disturbs this curve, but, curiously enough, if the in-

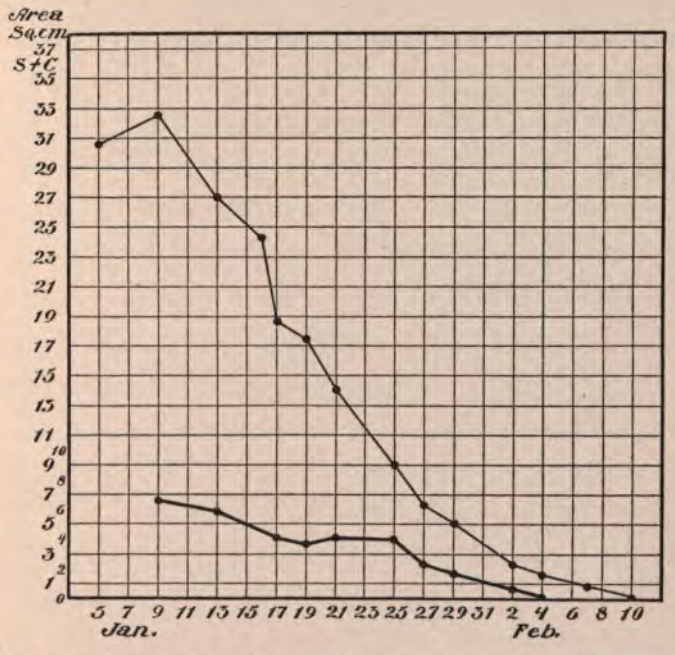

Fig. 22.—Shell wounds with fracture of the radius and ulna. The curves of both wounds tend to unite. Note that the larger wound, 33 sq. cm., healed far more rapidly than the smaller wound, which was less than 7 sq. cm. on the same date. (Kindness of Carrel and Hartman and the Jour. Exp. Med., 1916, xxiv, p. 442.)

fection is quickly overcome, the healing process undergoes acceleration and the healing will still be brought about at or very near the predicted date.

Of course, any prolonged infection would considerably delay the healing. Another curious fact brought out by these curves is that large wounds heal much more rapidly than small wounds (Fig. 22). (The whole subject is treated at length in the Journal of Experimental Medicine, 1916, vol. xxiv, pp. 451–470.)

Since this text was written I have been privileged to see in manuscript the paper presented at the Boston meeting of the American Surgical Association early in June, 1917, by H. D. Dakin, Walter Estell Lee, Joshua E. Sweet, Byron M. Hendrix, and Robert G. LeConte. It is entitled a "Report of the Use of Dichloramin-T (toluene-parasulphondichloramin) in the Treatment of Infected Wounds."

In spite of its immense value, three valid objections to the Carrel-Dakin method are evident:

1. The irritation of the skin, an irritation which sometimes is very painful and may persist for a long time. To minimize this it is essential not only to protect the skin by vaselin, but that minute care also be taken to insure the exact strength of the solution. Below 0.45 per cent. the germicidal action is too feeble. Above 0.50 per cent. the solution is too irritating. This means that the solution must be most carefully made and tested and that fresh solutions must be constantly prepared.

2. The solutions, when in contact with the wound exudates, lose their chlorin in an hour or even less time and become inert. Hence the need of a new supply of the fluid every two hours. This constant care, day and night, the care not to use too much or too little, the expense of so much solution, apparatus, and dressing, etc., make the method time-consuming and costly. Above all, it requires a large staff of doctors and nurses.

3. In order to obtain the maximum germicidal effect of weak hypochlorite solutions it is necessary to keep them in constant contact with all surfaces of the wound. In the Dakin-Carrel technic this is accomplished by making basin-like cavities of all the wounds, which means that dependent drainage must be avoided.

Accordingly, Dakin has lately suggested the use of Dichloramin-T, a synthetic chloramin corresponding to the germicidal chloramin formed when the nascent chlorin of the hypochlorites comes in contact with the wound exudates. Dichloramin-T is non-irritating to the skin. Instead of using this as an aqueous solution, as was first employed with Chloramin-T, it is dissolved in chlorinated eucalyptol and paraffin oils. This solution can be used in 5 per cent. and even of 10 per cent. strength instead of the 0.5 per cent.,

and the germicidal action continues for eighteen to twenty-four hours. The solution is said not to affect the body cells, even in the stronger percentages.

The dressing, therefore, is done only once a day; the technic is much simpler than the earlier one, and permits dependent drainage. There is a great saving of material, and, what is of greater consequence, the time given to each case, except at the primary operation or dressing, is greatly reduced.

At the Pennsylvania Hospital in Philadelphia Dr. Dakin's colleagues, in the paper referred to, have made comparative clinical tests, with the following results:

In 160 unselected cases of industrial accidents treated by the Dakin-Carrel method the Dakin-Carrel cases were discharged in one-third of the time required by former methods (as obtained from the industrial insurance statistics of similar cases in other Philadelphia hospitals)—a great advantage.

In 82 similar unselected cases treated in the same clinic by the Dichloramin-T-in-oil method they were discharged in 16.3 per cent. less time than by the Dakin-Carrel method—a still better result. These results, however, were obtained under the favorable conditions of civil life, in a first-class hospital, and in the absence of the intense infection seen in the present war.

For details of preparation and surgical treatment by the Dichloramin-T-in-oil method the reader must refer to the paper mentioned* and later papers which will appear stating the experience of those who have used the method. Undoubtedly they will report frankly the good, bad, or indifferent results, as the case may be. So marked a change in treatment must run the gauntlet of criticism by many shrewd and careful observers. A final judgment must be reserved until many surgeons have thoroughly tested the method. The method, as ought to be the case, has been freely given to the profession and the public.

The following are the directions for preparing the solution. Any good chemist can make it.

Those who are technically interested are referred to the chemical papers by Kastle, Kaiser, and Brady† and Chattaway.‡

PREPARATION OF DICHLORAMIN-T

The following details were worked out for Chattaway's method of preparation:

Chlorinated lime (from 350 to 400 gm.) of good quality is shaken with 2 liters of water on a shaker for

* Jour. Amer. Med. Assoc., July 7, 1917, and Trans. Amer. Surg. Assoc., 1917.

† Amer. Chem. Jour., 1896, xviii, 491.

‡ Jour. Chem. Soc. London, 1905, lxxxvii (1), 145.

half an hour, and then the mixture allowed to settle. The supernatant fluid is siphoned off and the remainder filtered.

Powdered toluene-parasulphonamid, 75 gm. (the crude product may be used), is then added to the whole of the hypochlorite solution and shaken till dissolved. The mixture is filtered, if necessary, placed in a large separating funnel, and acidified by the gradual addition of acetic acid (100 c.c.). Chloroform (about 100 c.c.) is then added to extract the dichloramin, and the whole is well shaken. The chloroform layer is tapped off, dried over calcium chlorid, filtered, and allowed to evaporate in the air. The residue is powdered and dried in vacuo. It is sufficiently pure for most purposes without recrystallization.

The sodium toluene-parasulphochloramin which is sold under the trade name of chlorazene may be used instead of the toluene-parasulphonamid.

A SECOND METHOD OF PREPARING DICHLORAMIN-T

Fifty gm. of para-toluenesulphonamid are dissolved in 500 c.c. of water, and 100 gm. of sodium acetate and 100 c.c. of chloroform are added. The container is immersed in cold water, and a rapid stream of chlorin is passed in until the mixture is saturated. The mixture is allowed to stand a few hours, and if the odor of chlorin disappears, more of the gas is passed in. If necessary, more chloroform can be a dissolve the dichloramin. From this point re is the same as in the preceding method.

PREPARATION OF CHLORINATED EUCALYPTOL

Eucalyptol (U. S. P.), not eucalyptus oil, must be used. Five hundred c.c. are treated with 15 gm. of potassium chlorate and 50 c.c. of concentrated hydrochloric acid. After twelve hours the oil is well washed with water and sodium carbonate solution. Dry sodium carbonate is added to the oil, and the mixture is allowed to stand twenty-four hours. It is then filtered and dried with a little calcium chlorid.

PREPARATION OF CHLORINATED PARAFFIN OIL

Five hundred c.c. of commercial liquid petrolatum are treated with 15 gm. of potassium chlorate and 50 c.c. of concentrated hydrochloric acid. The mixture is exposed to the light and allowed to stand over night. It is then put into a separatory funnel, and washed successively with water, sodium chlorid solution, and water. The opalescent oil is tapped off, a lump or two of calcium chlorid and 5 gm. of charcoal are added, and the oil is filtered with suction.

In order to determine the amount of liquid petrolatum which can be added to the eucalyptol solution of dichloramin-T the following mixtures were made:

Solution 1: 1 part liquid petrolatum to 2 parts 15 per cent. eucalyptol solution.

Solution 2: 1 part liquid petrolatum to 1 part 15 per cent. eucalyptol solution.

Solution 3: 3 parts liquid petrolatum to 5 parts 15 per cent. eucalyptol solution.

Solution 4: 2 parts liquid petrolatum to 1 part 15 per cent. eucalyptol solution.

These solutions were placed in test-tubes, stoppered tightly, and preserved in the refrigerator at about 0° C. All solutions became somewhat turbid as soon as the liquid petrolatum had been added, but in forty-eight hours there was no appreciable settling out in any case. After a week, however, the dichloramin-T had partially crystallized from Solutions 3 and 4. Solutions 1 and 2 were no more turbid than just after the addition of the liquid petrolatum, and none of the dichloramin-T had crystallized out.

This experiment seems to justify the conclusion that no more than an equal part of liquid petrolatum should be added to a 15 per cent. solution of dichloramin-T in eucalyptol when the solution is to be kept for any length of time, but when the mixture is to be used immediately, as much as two parts of liquid petrolatum to one of the 15 per cent. eucalyptol solution may be used.

We have used a solution made up of one part of liquid petrolatum and two parts of 15 per cent. solution of the dichloramin-T in eucalyptol. A larger proportion of the liquid petrolatum would make the mixture somewhat cheaper, but would have no other apparent advantage.

One sample of chlorinated eucalyptol and two samples of chlorinated liquid petrolatum, one of which was chlorinated in the sunlight and the other on a cloudy day, were analyzed for chlorin by Carius' method, with the following results:

Chlorinated eucalyptol:

0.1044 gm. oil gave 0.0044 gm. AgCl = 1.04 per cent. Cl.

Liquid petrolatum chlorinated on a cloudy day:

0.0936 gm. oil gave 0.0052 gm. AgCl = 1.37 per cent. Cl.

Liquid petrolatum chlorinated in sunlight:

0.1510 gm. oil gave 0.0231 gm. AgCl = 3.78 per cent. Cl.

The amount of chlorin which the oils take up is not large, but the amount absorbed is equivalent to a very considerable portion of chlorin which would be available from a 10 per cent. solution of the dichloramin-T.

REMOVAL OF FOREIGN BODIES

The removal of foreign bodies with the aid of fluoroscopy has proved so successful in the present war that I think it well to direct especial attention to the possibilities of attaining still greater efficiency and accuracy by the use of stereo-fluoroscopy. I, therefore, asked Dr. E. W. Caldwell to make the following brief statement of the general principles underlying it.

By his earlier thorough training as an electrical expert, and later his study of medicine, he is especially competent to consider this subject. I understand that he has perfected earlier methods and is still making improvements in the technic.

Stereo-fluoroscopy in the Localization and Extraction of Foreign Bodies

BY E. W. CALDWELL, M.D.
New York City

"There are many cases of injury by a foreign body in which the *x*-ray localization can be best made on plates, but experience in the military hospitals of Europe shows that in most cases the fluorescent screen method is preferable. These fluoroscopic localizations are carried out sometimes before the opera-

tion for removal, and sometimes in connection with the operation. The advantages of the last-mentioned method seem to compensate for its disadvantages, which are: First: The danger of infecting the field from the use of the *x*-ray apparatus. Second: The necessity for operating in a fairly dark room in order to see the fluorescent screen clearly. Third: The danger incident to the use of certain anesthetics in close proximity to electric sparks.

"The use of the fluorescent screen during operation is seldom needed, except in war surgery, and this procedure calls for refinements and improvements in technic and apparatus which in times of peace have not been fully developed.

"The most serious defect of the *x*-ray projection is that it is essentially a shadow, and not an image, and while it gives us fairly accurate ideas of length and breadth, there is ordinarily no indication of depth, such as is present in a photographic image.

"This defect has been remedied by the use of the stereoscope, or double-shadow method, first proposed by Elihu Thomson early in 1896,* and first carried into practice by Sir James Mackenzie Davidson in London.

"Stereoscopic *x*-ray plates have been in practical use since Davidson's first publication, and have been increasing in popularity in recent years. The stereo-fluoroscope was used experimentally by Davidson,

* New York Electrical Review.

myself, and others more than sixteen years ago, but it has not yet come into general use. This valuable accessory to the fluorescent screen seems about to be reduced to practice, and promises to be very helpful in the localization of foreign bodies, especially by the method of Sutton, in which a cannula containing a steel wire is pushed through the tissues under the guidance of the fluorescent screen until it is in contact with the foreign body.

"With the ordinary fluoroscopic method, which gives no perception of depth, it is rather difficult to tell when the needle is approaching the foreign body. The stereo-fluoroscope, however, shows the relation of the exploring needle to the foreign body as accurately as it could be seen if exposed in the open air.

"The process of obtaining a stereo-fluoroscopic image is much more complicated than that of simple fluoroscopy, but recent improvements in the *x*-ray tubes have removed many of the difficulties which existed in the first experiments some fifteen or eighteen years ago.

"In order to obtain the stereo-fluoroscopic image it is necessary to use two sources of *x*-ray, separated by a distance of a few inches, and to present to each eye the simple flat projection produced on the screen by one of these sources of *x*-ray. This is accomplished by exciting alternately the two sources of *x*-ray (ordinarily two small tubes placed side by side) and moving in front of the eyes a shutter which is synchronous with the alterations in the source of the *x*-ray, so that

when the right eye sees the projection from the left *x*-ray tube the shutter cuts off the vision of the left eye. Conversely, when the left eye sees the projection from the right-hand *x*-ray tube, the shutter cuts off the view from the left. Each eye, therefore, sees a slightly different projection, and the effect is that of two-eye vision, which gives a conception of the depth that is not obtained from the simple fluoroscopic shadow.

"In practice the flashes of the *x*-ray from each tube must follow each other so rapidly that the resulting *x*-ray shadow appears to be continuous. This requires a frequency of at least 15 or 16 impulses per second, and it is often convenient to use as many as 60 per second, which is the frequency of the usual commercial alternating current lighting circuit.

"The first apparatus of this kind, devised by Sir James Mackenzie Davidson,* made use of two induction coils with a mercury interrupter, operated by a small electric motor. To the shaft of the motor was connected a rotating disc shutter with properly placed slots, permitting each eye to see alternately and in synchronism with the alternating excitation of the two *x*-ray tubes.

"In this apparatus the position of the shutter had to be fixed because of its mechanical connection with the rest of the apparatus. Boaz and others used a flexible shaft for rotating the shutter and obtained some degree of mobility. My own first contribution

* Archives of the Roentgen Ray, January, 1901.

to the art* consisted in the use of a single tube with separated foci, and in the use of an electrically operated shutter, which was, therefore, freely movable and could be attached to the eye-piece of the ordinary fluoroscope. The alternating excitations of the tube were obtained by making use of an alternating current. The wave in one direction excited one source of *x*-ray, and the wave in the other direction excited the other source of *x*-ray. The moving shutter formed the rotor of a small synchronous electric motor operated from the same alternating current circuit which supplied current for the *x*-ray tube. At the present time this is the most convenient shutter available.

"In the last few years the development of the Coolidge tube, which can be operated perfectly from a high-tension alternating current, has made this problem very much simpler.

"Improved methods of supporting the tubes, the fluorescent screen, and the shutter have been developed within the last few months, and it is hoped that in spite of its complexity the apparatus may materially assist in the surgical removal of foreign bodies."

In Makins' paper† he and Major Curtis consider quite fully the use of radioscopy and stereo-fluoroscopy. They include also a consideration of the

* New York Electric Review, November 16, 1901.

† Brit. Med. Jour., June 16, 1917.

method of localization of foreign bodies by combining radiography and sectional anatomy, as described by Captain Crymble.* See also another important paper by Eastman and Bettman.†

* Brit. Jour. Surg., October, 1915.

† Annals of Surgery, July, 1917.

TETANUS

The infection of the soil and of the skin and clothes, the sealing of the wounds from drying of the blood, when speedy access to the first-aid station is impossible, so creating an anaërobic condition in the wound, the rapid growth of the bacteria in twenty-four hours or more in such favorable conditions (*vide supra*), all combined to cause many cases of tetanus in the early months of the war. In our Civil War the mortality was 89.3 per cent.; in the Franco-Prussian War, 90 per cent. Ashhurst and John,* in a paper covering 435 cases from 1897–1911, reported by 13 authors, still showed a mortality of 60 per cent. In the early stages of the present war there were necessarily many cases, because of lack of the tetanus antitoxin in sufficient quantities for such huge masses of wounded. At that time, too, the imperative need of an early protective inoculation had not been driven deep into the minds of surgeons, as has been the case later. Now every wounded man receives a protective inoculation at the very first possible moment. As Gibson

* Amer. Jour. Med. Sci., June, 1913.

insists, to wait for the symptoms of trismus is to court disaster. "Expect tetanus in all wounds and prevent its onset" is the rule, and the result has been that lockjaw has practically disappeared in the armies on both sides, unless in some distant post where the supply fails or when the patient receives the protective inoculation too late.

Now that the immediate injection of the antitetanic serum is universally practised by the surgeons in the armies on both sides, tetanus is relatively rare. Cases occur singly, rather than by dozens or scores. This conquest of tetanus is one of the notable victories of the war.

One peculiar phase of infection has been noted by Moynihan and others, viz., "the inordinate length of time microörganisms may remain in the tissues long after healing is complete" and then cause acute infection. Even after trivial operations for the removal of foreign bodies, or even for passive movements, tetanus may set in unexpectedly. "Delayed tetanus" and "delayed gas infection" are not very uncommon.

Bowling* records three cases under treatment at one time, delayed until the fortieth, fifty-first, and fifty-third days. In the forty-day case not only did tetanus set in after this period, but seventy-three days

* Brit. Med. Jour., March 4, 1916, p. 337.

after the wound had been received, and forty-two days after it had healed, gas gangrene also supervened and caused his death. Meantime his tetanus had yielded after the administration of a total of 189,500 units. No operative interference had occurred to light up these two infections. The other two cases had received antitetanic injections—one at an uncertain interval, the other two days after being wounded. Probably none had been given to the first (the fatal) case. Both of the other cases followed slight operations—one sixteen days after the mere opening of an abscess, the other four days after the removal of some clothing and part of the casing of a bullet.

In animals anaphylaxis following a second injection of the same serum is well known. But in man this is much less to be feared. Still, provision should be made to prevent its occurrence. It may follow a second dose of the antitetanic serum when this is given at an interval of ten to twelve days after the first dose. If, therefore, ten or twelve days after a prophylactic dose of the serum has been given, tetanus is threatened, the serum should be administered in fractional doses as follows: Instead of a full dose, an injection of only two or three drops of the serum in solution should be given; if no ill results follow again within ten minutes more, the full dose

may then be administered. Fractional doses should be the rule when any operations—even minor ones, such as described above—have to be done after an interval of ten to twelve days. If shock should occur, a few minims of a 1 : 1000 solution of adrenalin may be given hypodermically if the shock is not severe, but intravenously if it is at all alarming.

I append the Memorandum on Tetanus issued by the British War Office Committee on the Study of Tetanus:* The necessity of several successive protective doses is properly emphasized.

Memorandum on Tetanus

"*The Prophylactic or Preventive Treatment of Tetanus.*—The prophylactic value of injections of antitetanic serum is beyond all question, but there is strong experimental evidence that in about ten days the immunity conferred by the primary injection is to a great extent lost.

"It is, therefore, the general opinion that a second subcutaneous injection should be given in all cases of septic wounds, and in order to anticipate the total disappearance of the antitoxin from the body the second injection should follow the first at an interval of seven days.

"In cases of long-continued septic wounds, particu-

* Brit. Med. Jour., November 11, 1916, p. 647.

larly those caused by shell or bomb, third and fourth injections at seven-day intervals are recommended.

"It is self-evident that if it is considered necessary to give a second injection, then it is equally necessary to give a third or a fourth or further prophylactic injections, as the passive immunity conferred by the antitetanic serum is of short duration.

"It may be definitely stated here that the danger of anaphylactic shock is negligible when prophylactic doses of 500 U. S. A. units contained in 3 cm. of horse serum are given subcutaneously, whatever the interval after the preceding injection.

"*Dosage in Prophylactic or Preventive Treatment of Tetanus.*—The primary injection should consist of 500 U. S. A. units, and the second and following injections should be, for the present, of the same amount.

"The primary injection is given, as a rule, at a dressing station or field ambulance as soon as the wounded soldier is removed from the firing line. The second and following injections will most frequently be given at home hospitals. The ordinary phial usually contains 1500 units of tetanus antitoxin. One-third of a phial should, therefore, be injected into each wounded man. There is no necessity to sterilize the syringes after each injection—the serum is aseptic, and, moreover, contains an antiseptic; it will be sufficient if a freshly sterilized needle is used for each case.

"*Precautions to be Taken Before Operating on Wounds.*—When operations are performed at the site of wounds, even if they are healed, a prophylactic

injection of serum should invariably be given if the operation be performed at a greater interval than seven days from the last injection. Cases have occurred in which the performance of simple operations has been followed by an attack of tetanus, although in many cases the primary wound had been healed several weeks before the operation.

"This precautionary injection may consist of a single subcutaneous injection of the ordinary prophylactic dose of 500 units, given, when possible, two days before the operation.

"It is better to give it two days before the operation, as it takes some forty-eight hours for antitoxin to be fully absorbed after subcutaneous injection. Injected intramuscularly, the absorption is quicker,—said to be about twelve hours,—so that this method could be used if time is pressing.

"Of course, a larger dose than 500 units may be injected if thought advisable.

"*Antiseptics Which May be of Use in the Preventive Treatment of Tetanus.*—The group of oxidizing antiseptics, such as hydrogen peroxid, potassium permanganate, chlorin water, and solution of iodin, are particularly unfavorable to the anaërobic growth of the tetanus bacillus. They have the power of rendering toxin non-toxic.

"*Diagnosis.*—The classic symptoms of tetanus as described in the majority of the text-books refer to a phase of the disease when treatment has already lost much of its value. With many medical men tetanus

is not tetanus until the symptoms of *risus sardonicus* and lockjaw are present.

"In those who have been protected by prophylactic injection of antitoxin trismus and general symptoms practically never occur, and the manifestations of tetanus are confined to local spastic rigidity of the wounded limb, which may persist for weeks.

"The early diagnosis of tetanus is of the greatest importance. All clinical and experimental evidence tends to show that the chances of successful treatment diminish rapidly with the length of time after the first symptoms are observed.

"Tetanus toxin reaches the motor nerve cells by traveling up the nerves. It is not directly conveyed to the central nervous system by the blood. In a large number of cases the toxin appears to reach the spinal cord primarily by the nerves which are in connection with the seat of the injury, and hence the motor nerve cells governing the muscles round about the wound will be the earliest affected, such affection showing itself in the form of spasticity and increased reflex excitability of the muscles near the wound. In some cases these symptoms may precede other symptoms of tetanus by many hours. It is, therefore, desirable that the muscles in the vicinity of the wound should be examined whenever dressings are removed, and the occurrence of rigidity or twitchings, or local increased reflex response to gentle tapping or pressure, immediately reported to the surgeon in charge.

"*All nursing sisters engaged in dressing wounds*

should be warned to give the alarm if the muscles round the wound are harder or more rigid than the muscles of the uninjured limb or side. . . . . .

"*Therapeutic or Curative Treatment of Tetanus.*—It cannot be too strongly emphasized that time is the all-important element in the treatment of tetanus. As short a time as possible should be allowed to elapse between the diagnosis and the commencement of active treatment. A delay of an hour may make all the difference between success and failure.

"It is on this account that the early symptoms are of the greatest importance. In almost every case of tetanus there are found local manifestations of the disease, very often hardness and rigidity of the muscles around the wound, and these signs can be seen or felt for days or even weeks before the occurrence of trismus. In a case on record these local symptoms had been present for three weeks before the trismus showed itself and before tetanus was suspected. One medical officer is reported to have said that symptoms of tetanus were present in a case but were not sufficiently severe to justify the use of antitoxin! According to present ideas, it should no longer be permissible to wait for the occurrence of lockjaw before pronouncing the word tetanus; 5000 units of antitoxic serum are of more avail at the very beginning, when the disease is still localized, than 50,000 when the symptoms have become general. The moment, then, that *any* local manifestation of tetanus is observed,

it is recommended to proceed at once to vigorous specific treatment.

"The treatment of tetanus may be divided into specific and symptomatic:

"1. *Specific.*—Specific treatment consists in the giving of tetanus antitoxin, which has the power of rendering the tetanus toxin with which it comes in contact non-poisonous. From what has been said above about the injurious effect of delay, it is obvious that it is necessary to give antitoxin by the method which enables it to produce its effect most quickly. Subcutaneous injections of serum are absorbed very slowly; forty-eight hours may elapse before a dose is fully absorbed; hence little can be expected from this method at the beginning of treatment.

"Experimental and clinical evidence has shown that the best results are attained by intrathecal injections of serum. (See Appendix.)

"This direct attack on the toxin in the neighborhood of the central nervous system should be supplemented by intramuscular injections in order to neutralize any toxin in the blood, and thus prevent any more of it being taken up by the nerve-endings in muscle. Absorption of antitoxin from muscle is rapid, reaching its maximum in about twelve hours.

"In addition to the intramuscular method subcutaneous injections can be practised at any time, and is particularly useful in the later stages in keeping up the antitoxic quality of the blood. Absorption reaches a maximum in two or three days.

"It is recommended that intravenous injections should *not* be made, as the risks of anaphylactic trouble occurring are greater when serum is given intravenously than when it is given by any other route.

"*Dosage in the Treatment or Curative Treatment of Tetanus.*—When given curatively, antitoxic serum must be administered in very large doses.

"In a case of tetanus the first thing to do is to give an intrathecal injection of antitoxin.

"The amount of cerebrospinal fluid which can be withdrawn will, as a rule, not be more than 20 c.c. It is usually held to be undesirable to run in more serum than will replace the cerebrospinal fluid drawn off, and in the cases when little or no fluid can be withdrawn it is not wise to inject more than 20 c.c. of serum, *and this very, very slowly.*

"If the serum used be of the ordinary strength of 150 units in one c.c., the patient will then receive a dose of some 3000 in 20 c.c.

"If the serum be of higher potency,—say, 800 units to the cubic centimeter,—the patient will then have received 16,000 units. For intrathecal injections this high potency serum, if procurable, should by all means be used. At the same time 5000 to 10,000 units should be injected intramuscularly, and 3000 to 5000 may also be given subcutaneously.

"The intrathecal injections may be repeated daily for three to five days, when they should, as a rule, be discontinued. The intramuscular and subcuta-

neous injections may be continued daily or oftener, according to the severity of the symptoms. When the disease shows distinct signs of abating, the size of the dose may be gradually decreased, the interval between the doses lengthened, and the serum given only subcutaneously. . . . . .

"2. *Symptomatic.*—Symptomatic treatment consists in the exhibition of sedative drugs. Perhaps the most suitable is morphin in ¼ grain doses, administered every four hours; potassium bromid, chloral, chloretone, paraldehyd, are also given by the mouth or rectum.

"*Carbolic Acid.*—There is no convincing evidence that the carbolic acid treatment of tetanus has any curative effect whatever or any action upon the course of the disease.

"*Magnesium Sulphate.*—Treatment by sulphate of magnesium has no effect upon the disease itself. The cessation of spasm which follows an injection is only temporary, and is purchased at the cost of risks which are far more negligible. It is very doubtful if any real advantage is gained by its use.

"*Surgical Treatment of the Wound.*—There is a general impression that it is of advantage to excise the wound or amputate the limb in cases of tetanus. The matter is one upon which there is considerable difference of opinion. From the clinical experience of many observers it would seem that these procedures are of little avail, and may actually accelerate the course of the disease. Animal experiment, so far as

it goes, also suggests that operative measures are useless.

"While more evidence is required before any dogmatic statement can be made, it appears safer to abstain from surgical interference with the wound until the ordinary treatment for tetanus has been carried out, unless there exist other and imperative reasons for immediate operation.

"The irrigation of the wound with oxidizing agents, such as hydrogen peroxid, when this can be done without undue disturbance and without opening up the wound, is to be recommended.

"*Reporting and Care of Cases.*—In every Command one or more officers with special knowledge should be detailed . . . to visit and assist in treatment of cases of tetanus. These officers should be at the general hospitals of the district, and their names and telephonic addresses should be communicated to the officers and medical practitioners in charge of subsidiary hospitals.

"On occurrence of a case of tetanus the appointed officer will be immediately informed, and he will at once proceed to visit the case and offer assistance in the carrying out of such treatment as has been suggested in the present memorandum. He will, if necessary, assist in the operation of lumbar puncture and intrathecal injection. This will seldom be necessary, as from what has already been said as to the danger of even an hour's delay this intrathecal injection will usually have been done before his arrival,

unless the distance to be traveled is short. He will make careful inquiry into the case in order to ascertain if any early symptoms had been present and had escaped notice. He will note what prophylactic injections had been made, and if omitted, why they were omitted. When visiting the hospital where the case has occurred, he will ascertain if the other wounded men are receiving prophylactic injections. He should see that sufficient notes of the case are being kept in order that the tetanus form can be filled up as fully as possible. For example, it is very seldom that the distinguishing marks on the bottles of serum are reported. If serum trouble arises, it is evident that this information would be useful. He will forward an inspector's report to Surgeon-General Sir David Bruce with as little delay as possible. The ordinary tetanus report will be filled in by the medical officer in charge of the case. [In the United States Army this report would go to the surgeon's immediately superior officer unless other special orders had been issued.]

"Officers in charge of hospitals will be responsible for the administration of the second and following prophylactic doses of antitoxin to all wounded under their care unless reasons exist for withholding them. The administration of antitoxin will be recorded on the case-sheet. They will also, as heretofore, inform Surgeon-General Sir David Bruce, by telegram, of the occurrence of a case of tetanus, and on the death

or recovery of the case, forward the usual tetanus report in accordance with War Office instructions.

"Any abnormalities of behavior of antitetanic serum should be carefully noted and reported.

"As the Tetanus Committee was appointed for the purpose of studying tetanus, it is greatly to be desired that every medical officer will coöperate in a collective investigation, and submit any evidence in his possession which may add to our knowledge of the disease and its treatment.

"War Office, S. W., October 25, 1916."

Appendix

The Method of Performing an Intrathecal Injection

"The patient should preferably be under general anesthesia, but the operation can be performed with local anesthesia. The skin over the area of the fourth and fifth lumbar spines should be painted with iodin or cleansed with soap and water, followed by an antiseptic. A spinal needle and 20 c.c. syringe should be boiled in normal saline, *and the surgeon must observe throughout the most rigorous aseptic precautions.*

"The patient is bent head to knees, so as to present as fully a curved back to the operator as possible, and the position of the fourth lumbar spine ascertained by drawing an imaginary line between the crests of the ilia.

"The tip of the finger is placed on the supraspinous ligament connecting the summits of the spinous processes of the fourth and fifth lumbar vertebræ. The

needle is inserted about three-eighths of an inch to one side of the middle line, and directed forward and slightly upward and inward. If the needle strikes the bone, it should be withdrawn and a fresh attempt made. The canal is reached at a depth, on an average, of about 2½ inches (5 cm.). The trocar is withdrawn, and about 20 c.c. of cerebrospinal fluid allowed to flow out into a measured vessel. The syringe is then fitted to the needle and the serum injected.

"It is important that the serum be heated to the temperature of the body and the injection made very slowly.

"The canal can also be reached by pushing the needle through the supraspinous ligament in the middle line, half-way between the two spinous processes.

"If several injections have to be made, it is well to choose fresh sites.

"Blocking of the flow of the cerebrospinal fluid by a blood-clot may be overcome by reinserting and withdrawing the trocar.

"The bed should be tilted at the foot and the pillow removed for an hour or two after the injections."

GAS INFECTION AND GAS GANGRENE

The difference between these two conditions should be noticed.

Gas infection is very common in the wounded in the present war. As Bowlby notes, it is practically unknown in Great Britain. The same is true in the United States. Personally I never saw a single case in the Civil War, and but one case in civil life since then. In the present war Taylor notes the presence of the gas bacillus of Welch in 70 per cent. of the cases. Fleming* found it in 103 wounds out of 127, and in the clothing in 10 out of 12 cases. Fortunately the infection can be controlled with much success if it be seen and treated early.

Gas gangrene, on the contrary, is a result of progressively developed infection and is a most dangerous condition.

The cause is most commonly the bacillus of Welch —B. aërogenes capsulatus, often called B. perfringens by the French. Other gas-producing bacteria are also found.

* Lancet, September 18, 1915, p. 638.

The rapidity of the growth of the bacillus of Welch, and therefore the urgent need of instant and radical action, is best appreciated by Kenneth Taylor's method of obtaining a pure culture:* A series of six or more culture-tubes are inoculated, each tube from its predecessor, at intervals of only half an hour. Even in this short interval bubbles of gas become evident in the successive tubes. By the sixth or seventh tube one may obtain a pure culture, so far has the gas bacillus outgrown all other germs. The bacteriologist and the surgeon should always coöperate.

Tissier's observations† are illuminating. Working on wounds in the present war, and by animal experimentation, he has shown the following noteworthy facts: Filtered cultures of the Welch bacillus and of that of malignant edema were inert. Unfiltered cultures were followed by only a hard edema, which gradually disappeared. If, however, there were added to the Welch bacillus aërobic cultures, *e. g.*, of the enterococcus, then a guinea-pig would be killed in three days; if it were the staphylococcus albus, death followed in twenty-four hours; if the streptococcus was added, death followed in fifteen hours. This

* "Pathol. and Bact. of Gas Gangrene," Jour. Path. and Bact., 1916, xx, 384.

† Ann. Institut. Pasteur, December, 1916.

marked difference he attributes to the restraint on the anaërobes by the oxygen in the circulating blood. The observation of Bowlby that he has never seen gas gangrene in the head, and almost never in the neck, affords strong support to this view, as their blood-supply is far more abundant than that of any other part of the body. The addition of the aërobes removes this restraint. The latter, so to speak, prepare the soil and allow the anaërobes then to play their destructive rôle. For the first six to eight hours the wounds contain few bacteria; by the tenth hour the anaërobes begin to multiply rapidly; by twelve hours they are the dominant growth.

Clinically also the same astonishingly rapid development is seen. Bowlby* has observed well-marked infection with formation of gas within five hours, and death from gas gangrene of an entire limb in sixteen hours.

All foreign bodies (clothing, etc.) in the wound, as they will keep up the anaërobic infection, must be removed; *all* dead tissue must be removed, the wounds kept open, and frequent antiseptic dressings used. My own impression is that Dakin's fluid, Taylor's quinin chlorhydrate, and possibly some other antiseptics, when properly used in connection with the

* Brit. Jour. Surg., 1915–16, 151.

above absolutely necessary means, will enable the surgeon to conquer the infection at the start, if he sees the patient as early as possible—certainly within the first twenty-four hours. If the infection has gained headway and gas production has already set in, then the treatment by incisions and all means to facilitate the escape of the gas, and nothing which will hinder it, with further removal of dead tissue and the continued use of the chosen antiseptic, especially by Carrel's method, in many cases will result in cure; if gas gangrene has actually occurred, certainly if it is extensive, then immediate amputation will be needful in many, if not in most, cases.

While the blood often contains the gas, the bacillus itself is not often found in the blood. It is chiefly a saprophytic bacillus, the gas being produced by the destruction especially of the muscular tissue, accumulating at first in between the muscular bundles. A detached arm or leg will sometimes float in water because of the great quantity of gas in it. In the intramuscular spaces it quickly compresses the muscular tissues mechanically until it bursts the sheath. Meantime necrosis of the tissue occurs, and a severe toxemia may easily follow—not from the gas itself, since Taylor believes he has shown that the bacillus itself is not toxic, but from the toxic products of the necrotic muscles.

Treatment.—The paramount importance of the earliest possible treatment during the first stage of rapidly spreading infection, before the production of gas in any serious quantity has occurred, is self-evident. Every hour counts against the patient.

Taylor* points out clearly what is to be done:

1. Destruction of the bacillus.

2. Removal of the tissue especially favoring its growth, *i. e.*, the necrotic muscles.

3. Measures to prevent the destruction of the muscles as a result of mechanical pressure.

For the destruction of the bacilli Taylor recommends a one per cent. solution of chlorhydrate of quinin. Others have found Dakin's fluid effective.

Bowlby (see his letter, p. 131) has noted the almost entire absence of gas gangrene in the head and neck. This he attributes to the unusually large blood-supply carrying a large amount of oxygen. As the bacillus of Welch is an anaërobe, oxygen is inimical to its growth. Depage has used injections of oxygen into the tissues infected with the Welch bacillus with advantage—probably for the same reason.

The muscles should be explored by numerous longi-

* "La Gangrene Gazeuse," Arch. de Méd. et de Pharmacie Militaire, 1916; Lancet, September 4, 1915, 538, and January 15, 1916, 123; Brit. Med. Jour., December 25, 1915, 923.

tudinal incisions, incisions of the muscular sheaths, and the excision of all necrosed tissue. Sometimes single muscles or a group of muscles may need to be excised. The dead muscle can be distinguished from the living by its dirty brick-red color, in contrast to the normal purple-brown. The dead muscles also lose their contractility. The focus of infection, if known, should be excised. The wound should be dressed with the chosen antiseptic solution. The incisions should be kept open by light gauze compresses wet with this solution. No circular bandages which can exert the least compression, and so hinder the escape of the gas, are allowable. Nothing should obstruct the free escape of the gas. Everything should promote it.

If gas gangrene occurs or has already set in, the same free incision should be made, unless this has already been done.

Bacteriologic diagnosis in the early stage is most important. Soon the discoloration of the skin, blebs, and crepitation make the diagnosis positive, but crepitation often appears late rather than early. The *x*-ray may disclose the bubbles of gas in the tissues. On incision, if the muscular tissue is bloodless, pale, dry of a brick-red color, gangrene already exists.

judgment then will be required to decide

whether free excision of this gangrenous tissue, with suitable subsequent dressing, or immediate amputation should be done. If the limb is amputated, it should be by the so-called "guillotine" method, *i. e.*, without flaps. The wound should be dressed with the end of the stump entirely uncovered until the infection has been conquered. Then the skin may be drawn down by lacing or by weights and sutured as soon as feasible. The bone may have to be shortened.

AN ANTITOXIN TO PREVENT GAS GANGRENE

One of the most important contributions to surgery as a result of the war has appeared just as I am correcting the proof of this Report, in a paper by Carroll G. Bull and Miss Ida W. Pritchett, of the Rockefeller Institute.* It greatly extends, in fact may be said to revolutionize, our knowledge of the pathology of gas gangrene and its cause, and, what is still more important and cheering, has given us the promise of an antitoxin which it seems not too much to expect will be as potent for the prevention of gas gangrene as the antitetanic, antityphoid, and other similar antitoxins are in preventing these latter maladies.

Experiments on animals, by using four strains of

* Jour. Exp. Med., July, 1917.

the B. Welchii from wounds in the European War and one from the lining of an old overcoat at home, have led to "the discovery of the conditions under which a highly potent, soluble toxic agent is regularly produced by the bacilli, on which their poisonous or lethal action chiefly if not wholly depends."

This powerful soluble toxin sometimes killed animals in from a few hours to a few minutes, and even almost instantly.

"The cause of death in *Bacillus Welchii* infection is not a blood invasion of the microörganisms and not acid intoxication, but an intoxication with definite and very potent poisons produced in the growth of the bacilli in the tissues of the body. . . ."

"The poison or toxin is a complex of an hemolysin and another poisonous body. The latter is the more toxic, since it may bring about death under conditions in which no blood destruction takes place.

"The experiments briefly reported . . . seem to possess considerable importance. They indicate, indeed, that in *Bacillus Welchii* infection in nature the development of the spores into vegetative bacilli may be prevented by a protective inoculation of an antitoxic serum, and also that the vegetative bacilli may be deprived by such a serum of their toxic products, which now appear to be their real offensive instrument. We are confronted, therefore, not only with a new point of view regarding the manner of

the pathogenic action of the Welch group of bacilli, but also with a new means of combating their pathogenic effects.

"The experiments presented appear to admit of one interpretation only; namely, that the Welch bacilli, under suitable conditions of growth, produce an active exotoxin, to which their pathogenic effects are ascribable. The toxic product, moreover, acts upon the local tissues and the blood in a manner identical with the action of the cultures. With the toxic product animals may be immunized actively and an immune serum which neutralizes the toxin perfectly and in multiple proportion be secured. The toxic bodies would seem to be at least two in number: one causing blood destruction, hence an hemolysin, and the other acting locally on the tissues and blood-vessels, causing edema and necrosis and probably exerting general toxic action in addition."

These views differ greatly from those current up to the present time. To me they seem to be based on ample experiments and on sound reasoning. Dr. Welch himself has expressed his approval of the conclusions. Some of the antitoxin I understand has already been sent to the surgeons in the field. The results of their tests on the wounded will be awaited with the deepest interest, and it is to be hoped will be conclusively favorable. Doubtless time will also bring

improvements in the method as a result of actual use of the antitoxin.

Makins, on page 794 of his paper (*loc. cit.*), makes an interesting reference to "Hospital Gangrene," of which, in common with all our surgeons, I saw so much during our Civil War. His description would apply fairly well to those cases, though the rapidly spreading destruction seen in our Civil War cases is not emphasized by Makins. Since then hospital gangrene has entirely disappeared. We do not even know its pathology or its bacteriology. Makins says:

"One form of streptococcus infection deserves special mention as possibly corresponding to the variety of 'classical hospital gangrene' described as the membranous. Cases of this nature have not been common, although sufficiently so to have become familiar. A wound which has previously been apparently progressing favourably becomes covered with a dense grey tough membrane, firmly adherent to the subjacent granulations. In the earliest stage this membrane does not materially differ from the thin layer of coagulated fibrin and included leucocytes which not uncommonly forms in cases of streptococcic infection which after a time fail to respond to treatment. The same cessation of free discharge from the wound surface is observed, a condition well de-

scribed by Colonel Sir Almroth Wright as 'lymph bound.' The membrane then thickens so as to resemble one of the diphtheritic class; in fact, strong suspicion was aroused in the earlier stages of the war that the change was due to a diphtheritic infection. Bacteriological examination has, however, in all cases resulted in the discovery of streptococci alone." . . . "Amputation is usually followed by a recurrence of the same type of wound surface, and the patient dies in from four days to a week's time after the commencement of the process. No successful method of dealing with this special form of wound infection has been devised."

Our treatment during the Civil War was empirical but was bacteriologically correct. The patient being almost always etherized, the whole wound was cauterized by nitric or nitro-muriatic acid, the acid nitrate of mercury, pure bromin, or the actual cautery. This effectually sterilized the wound. When the slough separated, it was treated as any other fresh wound.

WOUNDS OF THE HEAD

In spite of steel helmets, wounds of the head are exceedingly numerous. This is owing to the universal use of trench warfare and on a scale hitherto unknown. While many of these cases find their way into the hospitals, a still larger number die even before they can be collected or sent to a hospital.

"One of the lessons which has been taught us," as Cushing has well pointed out, is that "judgment comes only from special experiences." Two of the best illustrations of the value of experience are seen in the Surgery of the Head and the Surgery of the Jaws: "Only experts can make 50 per cent. of lacerated faces and jaws capable again of army crusts."

Among the communications in the journals dealing with cranial wounds, one of the most judicious, as one would naturally expect, is that by Dr. Harvey Cushing.* His "conclusions" seem to me to be so excellent that I quote them in full:

"There is a fairly universal agreement that almost all cranial wounds produced by projectiles, even

* Military Surgeon, June–July, 1915.

though they appear trivial, require surgical investigation, with the possible exception—(1) of certain of the tangential longitudinal sinus injuries, which, according to Sargent and Holmes, have a high degree of spontaneous recoverability, and which, when investigated, present unusual surgical risks; and (2) of certain of the fractures of the base due to perforating wounds, owing to their inaccessibility.

"There is, however, a wide divergence of opinion as to when and where these operations should be performed. It is recognized that cases treated immediately at a field ambulance appear to do well for a time, but are apt to suffer from complications after their evacuation. These complications are often ascribed to the patient's transportation, whereas they are due, in greater probability, to the fact that these early interventions of necessity are hurriedly undertaken and imperfectly executed, and that the wounded must oftentimes be evacuated at about the time when complications from sepsis are likely to occur.

"With the exception of the more serious injuries with extensive hemorrhage, in which surgical measures are practically unavailing, craniocerebral wounds, as a rule, present no immediate urgency, for as a tissue the brain is notably tolerant of contusions and infections. Hence a delay of two or three days in forwarding this class of wounded with expedition to a suitable base is preferable to the delay of two or three days in having them recover from

the effects of an incomplete procedure before transportation.

"One can rarely tell, from the external appearance of these wounds, how serious a matter the intracranial exploration will prove to be, and if the procedure is abandoned after a trifling crucial incision with a possible trepanation and the removal of a few fragments of bone and clot, followed by a gauze pack, a herniation, fungus, and infection will often ensue.

"Even apparently trivial scalp wounds may in the end require extensive and elaborate operations, which demand a thorough neurologic study, fluoroscopy, or *x*-ray plates, a carefully planned and deliberate intervention under skilful anesthesia, and the aid of such accessories for the extraction of certain types of missiles as an electromagnet. Accurate closure of the operative wound is desirable, and direct drainage, particularly by gauze, of the area of denuded cortex should be avoided if possible. The success of such a procedure is greatly handicapped by earlier direct enlargements of the original wound."

Especially do I indorse, on general principles, his advice that the only proper hospital to interfere surgically with a cranial wound is one in which facilities in skilled men, both neurologic and surgical, and the best *x*-ray apparatus are to be had. I am [illegible] that at present (May, 1917) some hospitals,

much nearer to the trenches than formerly, are thus equipped. An incompletely studied case and an indifferent facility for diagnosis and operation have no place in cranial wounds. The late results of such surgery are lamentable.

Gutter wounds may comminute the skull and produce serious intracranial lesions. These, as Cushing points out, have been often incompletely operated on at busy first-line hospitals and passed on with gauze packing, thus inviting infection.

For hemorrhage he advises Horsley's suggestion, viz., the implantation of raw muscle often to be obtained from the flap itself.

The wound should be most carefully cleansed and the edges resected. The opening in the bone should be freely exposed by a large flap and the opening enlarged sufficiently for inspection and such operative measures as are deemed necessary.

The dura should not be opened save to evacuate blood-clots or evidently disorganized brain tissue, to tie bleeding vessels, or for a formal decompression. In these always violently infected wounds this is of especial importance. I cannot subscribe to Burckhardt's statement* as to the innocuousness of such incisions. It is best to close the dura and the over-

* Bruns' Kriegschir., Heft 19, p. 618.

lying galea and scalp immediately to avoid a fungus cerebri. Efficient drainage should be provided. For this purpose rubber tissue is far better than gauze.

Decompression operations may relieve increased intracranial pressure. Sargent and Holmes* have used with advantage contralateral decompression. This has the great advantage of being done in clean tissue. If, however, the decompression is done on the same side as the wound, then to protect the brain from the infected scalp flap they recommend that the scalp be widely loosened from the skull, and that one or two pedunculated flaps of pericranium be slid over the brain and carefully sutured in place, followed by closure of the scalp wound.

In operations on cranial wounds, when possible, access should be had through an independent clean incision rather than by enlarging the almost certainly infected original wound. Foreign bodies in the brain should be extracted as soon as a complete operation can be done, for in this war practically all such foreign bodies are infected. But the surgeon must use his good judgment and not venture beyond the limits of reasonably legitimate surgery. Sometimes a secondary operation at a much later date will be best. Between the danger of infection and the danger

* Brit. Med. Jour., March 27 and November 30, 1915.

of operation only a large experience and good judgment can decide. Occasionally a powerful electromagnet may remove a missile, provided it is of a metal which is amenable to such treatment. The vibrations caused by an intermittent current may aid in loosening the foreign body. The value of the *x*-ray, especially in the present improved forms, is insisted on.

Bowlby* recommends permanent special hospitals for such cases. These have been developed by the British as a result of experience, by which we should profit. Whether a case can bear immediate transportation is decided largely by the pulse. If it be rapid, the patient should not be forwarded at once. A slow pulse favors the presumption of possible recovery. Such patients, as a rule, will bear transportation lasting even for two or three days. Moreover, an immediate operation at or near the front is not only apt to be an incomplete operation, but is often followed by a great drop in the blood-pressure. A moderate delay is a benefit. He summarizes the treatment as follows:

"A primary cleansing of the wound. The transmission of the patient as soon as possible to the hospital, where he will convalesce. The taking of *x*-ray

* Brit. Med. Jour., June 2, 1917.

pictures. The excision of the scalp and bone wound. A limited and careful removal of foreign bodies. The covering of the exposed brain. The closure of the wound, with superficial drainage, and a prolonged rest in bed."

These views are reinforced also by Makins,* who says:

"Examination of a considerable number of patients some months after their return to England proved much more satisfactory than had been generally expected. It was found that the proportion of patients who die after transference to England is small; later complications, such as cerebral abscess, are comparatively rare, and serious sequelæ, such as insanity and epilepsy, are much less common than had been foretold. In only 15 per cent. of the patients examined, however, had more than one year elapsed from the date of the injury. It also appeared that many patients with foreign bodies deeply lodged in the brain recover, and are scarcely more liable to serious complications than men in whom the brain has been merely exposed and lacerated. These conclusions are obviously tentative, but as far as they go appear hopeful."

Sargent (in Bowlby's paper), from a very large experience, confirms the same:

"The very large experience gained of gunshot

* Brit. Med. Jour., June 16, 1917.

wounds of the head has led to a considerable degree of modification in their treatment. Immediate routine operation, often incomplete, and, in the absence of full neurological information and *x*-ray examination, sometimes unnecessary and even misdirected, is no longer widely practised. It has long since been made abundantly clear that early evacuation of operated cases is often followed by disaster. As it is impossible to operate upon these cases and to retain them at the clearing stations for a period which renders transportation safe, more especially during times of great military activity, the practice now generally adopted is to transfer them without operation as soon as possible to hospitals further down the line. It has been made quite clear that surgical intervention is rarely required for the relief of cerebral symptoms, whether general or focal. Its chief aim is the prevention of intradural infection. On this conception all cases of gunshot wounds of the head fall into one of two categories, according to whether the dura mater has or has not been penetrated. Non-penetrating wounds have a low rate of mortality, whether operated upon or not, provided that the surgeon respects the integrity of the dura mater.

"It is customary, therefore, to do in these cases only as much as may seem advisable to ensure speedy healing, such as excision of the edges of the wound, removal where necessary of bony fragments, and partial or complete closure of the gap in the scalp either by suture or by some form of plastic operation."

Penetrating wounds should be treated conservatively, as indicated by Bowlby.

As to retained missiles, Sargent says:

"Removal of bullets, even when the wounds have healed and the risk of septic infection thereby is largely diminished, must be, even in skilled hands, attended by an amount of damage which, in most cases, would have more serious neurological consequences than could the presence of an aseptic bullet.

"Primary removal of a deeply seated missile carries with it the additional risk of septic infection. For these reasons the usual practice is to leave alone such missiles."

This corresponds to what I often stated to my students and always acted on to advantage. "If the surgeon, by seeking to extract a missile retained in the brain, will do more harm then the missile, do not operate"—and vice versa.

Holmes and Sargent,* after a study of over 70 cases, have described "The Longitudinal Sinus Syndrome." The paper cannot well be summarized, but their conclusions as to treatment are concise and reasonable. As a rule, do not operate. If operation be done, secure ample access to control the almost cer-

* "Injuries of the Superior Longitudinal Sinus," Jour. Royal Army Med. Corps, 1915, xxv, p. 56.

tain serious hemorrhage which can often be controlled by Horsley's method.

Makins rightly calls attention to a valuable paper by Lister and Gordon Holmes entitled "Disturbances of Vision from Cerebral Lesions, with Especial Reference to the Cerebral Representation of the Macula."* It is fully illustrated and is a most important contribution both to cerebral localization and to the physiology of vision. It is particularly creditable that men so constantly overworked should persistently continue their scientific researches.

* Proc. Roy. Soc. Med., 1916, ix, Section on Ophthalmology, p. 57.

WOUNDS OF THE CHEST

Herringham* bases an excellent paper on 211 cases. The conclusions are much the same as one reaches in civil surgery. If the patient is profoundly collapsed, as is naturally more often the case than in civil life, on account of the wholly different conditions, the heart-beat may not even be perceptible. Rest for a day with heat and morphin in suitable doses will often bring about great improvement.

An open external wound, allowing the free flow of the air in and out, causes generally a very distressing dyspnea. Hence if it is small it should be closed by strapping.

If it is larger and therefore practically certain to become infected if left so, remove any loose bone, round off the edges and the ends of the bones, and if possible close the wound by drawing the muscles and skin over it. If it cannot be entirely closed, a drain may have to be inserted. Herringham then recommends filling the cavity with an antiseptic.

More or less intrathoracic hemorrhage is the rule in

* Brit. Med. Jour., June 2, 1917.

wounds of the chest. If the effusion does not rise above the middle of the scapula nor in front of the midaxillary line, it does not cause much distress. Happily this represents the majority of wounds of the chest. "Watchful waiting" then should be the rule. After seventy-two hours there is little danger of further hemorrhage; if need be, such cases may then be evacuated without serious danger.

If the effusion increases so as to displace the heart and the pulse rises to over 100 and the respiration to over 32, the chest should be aspirated, and according to what is found the patient may be evacuated or a formal operation be done, by rib-resection, with free drainage.

If the *x*-ray shows a foreign body in the chest when the patient first comes under observation after being wounded, on the succeeding day, or even the same day, if his condition allows, this should be removed and the wound entirely closed after disinfection. In a moderate percentage such cases make a speedy recovery.

WOUNDS OF THE JOINTS

The military surgery of joints is, *par excellence*, that of the knee. Bowlby's remarks on these injuries* are well worth quoting in part:

"A great change for the better has taken place in the results obtained in the treatment of wounded joints. . . .

"Experience was chiefly gained on the knee-joint, for it is the joint most frequently hit, most easy of inspection, and its infection is followed by disastrous consequences more often than in the case of other articulations. . . .

"The first improvement was the abandonment of the intra-articular drains. The next was the excision of the wound, the removal of any foreign body, the flushing of the joint, and in some cases the closure of the capsule and the insertion of a superficial drain. . . .

"The next step was perhaps a bold one. As soon as possible after the receipt of the injury—that is, in the casualty clearing station—the wound was excised, the joint opened, cleaned, and irrigated, and then the whole wound in the synovial sac and the

* Brit. Med. Jour., June 2, 1917.

superficial tissues was tightly closed. It was certainly astonishing how seldom infection followed such treatment, even when fragments of shell or pieces of clothing had been removed from the joint; but for its success it is essential that the incisions around the wound edges should be carried quite clear of all infected tissue, and that the strictest asepsis is assured.

"Now, every knee-joint with such a wound is given the chance of healing by first intention, although the closure of the joint defect may entail the performance of a plastic operation to provide an adequate cover with a flap of synovial membrane or skin. Even if some infection does follow the closure of the joint, it is well not to be in too great hurry to lay the articulation open, for a certain number of such joints do settle down and provide a better limb than if submitted to more active treatment.

"When the joint wound is complicated with fracture of bone it may still be possible in some cases to close it with success. In cases of compound fracture of the patella with loss of substance, partial or complete removal of the fragments, and the provision of a skin flap, will often be followed by primary healing.

"When the tibia or femur is involved the case becomes more serious. Of the two fractures, that of the tibia is the most to be feared."

The "bold step" of primary closure of the joint is clearly justified by the following statistics from a table including 845 cases of injury to the knee-joint

at the Rouen hospital, quoted from Barling by Makins,* a part of which I reproduce, is very impressing. The contrast as to re-operation between the cases of excision and *closure*, and excision and *packing*, is most instructive.

1.	Total cases of injury to knee operated on	845
2.	With bone injury	438
3.	Without bone injury	407
4.	Wound excised and closed	322
5.	Cases with wounds excised and *closed* requiring further operation	82 = 25.5 per cent.
6.	Wound excised and packed	336
7.	Cases with wounds excised and *packed* requiring further operation	128 = 38.4 per cent.

* Brit. Med. Jour., June 16, 1917.

ABDOMINAL WOUNDS

The experience of the Boer War led us toward abstention in abdominal wounds unless there was suspected hemorrhage or fair evidence of visceral lesion. This was due to the small jacketed bullet, which not seldom traversed the abdominal cavity without wounding any viscera.

In this war, especially of late, the bomb, grenade, and high explosive shell have changed all this. Rarely, in case of penetration, do the viscera escape. Hence the burden of proof has been shifted. Abdominal section is now the rule unless there is good reason to believe that the viscera have *not* been wounded.

Wallace and Hughes and Rees* give encouraging statistics as to operative interference in abdominal wounds, showing a reduction in mortality of some 10 per cent. at the front. The importance of the earliest possible operation is emphasized especially by the figures of the last two surgeons. Patients operated on within the first six hours (43 in number) showed a

* Lancet, April 28, 1917.

recovery percentage of 62.8 per cent. In those operated on between six and twelve hours (33 cases) this had fallen to 36.3 per cent. In operations done between twelve and sixteen hours (18 cases) it had fallen to 16.6 per cent. After over twenty-four hours (11 cases) the recovery rate rose to 45.4 per cent. This can be readily accounted for on the ground that the more seriously wounded had already succumbed before reaching the hospital.

A good illustration of how a hospital may be suddenly flooded with operative cases is given by Lockwood and his colleagues.* After being rushed with the wounded from four days of continuous active fighting, suddenly in one night, between 9 and 12 o'clock, 96 operative cases—one every two minutes—were received. Of these, 36 were abdominal cases, and of these, 32 were operated on. One significant statement is that the surgeon "was usually obliged to operate alone."

Not uncommonly the missile reaches the abdomen through the back and the buttock, as well as from the front.

It is very often a question whether operation should be done at once after the patient has been

* Lockwood, McGill, Kennedy, MacFie, and Charles: Brit. [illegible]r., March 10, 1917.

transported over a rough road, and it may well be in marked shock and, in the cold weather, chilled through. Of course, if there is evident hemorrhage, or a strong suspicion of it, immediate operation *must* be done. The usual restoratives, and if possible the measures advocated by Porter (*vide* p. 14), may be resorted to if the patient's condition requires them. Lockwood and his colleagues base their decision chiefly on the pulse. If this is above 120 beats, operation should be deferred for a reasonable time for reaction to set in. All foreign bodies must be removed at whatever cost. If left behind, it is practically a sentence of death.

Both Lockwood and his colleagues and Fraser and Drummond, in the same issue of the Journal, note that there may be a flaccid abdomen instead of rigidity. This is seen also in civil life, especially when shock and intestinal hemorrhage combine to exhaust the patient and before protective muscular rigidity has set in as a result of beginning peritonitis.

The small intestine may exhibit multiple wounds, not only as in civil life, by multiple perforations from a single missile, but in this war especially from multiple missiles from exploded shell or shrapnel, to say nothing of additional wounds elsewhere in the body (*cf.* p. 30). One excellent piece of advice is given

by Fraser and Drummond: First, determine how many wounds of the intestine there are, their extent and locality, before deciding on the proper treatment. Then identify the cecum and then trace the small intestine from there upward. "As each perforation of the gut is exposed it is wrapped up in a small moist swab." The tape attached to the swab "is slipped through the mesentery and doubled twice around the gut." This avoids escape of the contents and additional infection, and gives one at a glance the means of judging what should be done. Special care should be taken not to overlook wounds of the posterior wall of the stomach and of the colon.

Since Crile has preached the "gospel of gentleness," no good surgeon will handle bowel or other viscera roughly or expose more than a foot or two at a time, nor dally with his operation. Speed, but never haste, is the rule. This is especially necessary when scores of cases may be urgently needing surgical relief.

As a rule, wounds susceptible to suture should be so treated even when there are several of them. Not seldom, however, a serious question will arise whether suture or resection should be resorted to. Most civil surgeons, I think, much prefer to avoid resection if possible. The authors of both the papers

just referred to—in all, six authors, who between them had treated 800 abdominal wounds, an exceptional experience, which entitles their final judgment to special weight—are decidedly of the same opinion. Fraser and Drummond go so far as to say that the only condition warranting resection is extensive damage to the mesentery or extravasation between the two layers of the mesentery at its attachment to the bowel where the latter is partially not covered by the peritoneum.

Their reason is the profound shock which attends resection and which may easily turn the scale against the patient. Too many of us, in civil life, at least, do not give sufficient weight to this reason.

If resection has to be done, Lockwood and his colleagues prefer end-to-end suture; Fraser and Drummond, and Bowlby prefer lateral anastomosis, so as to avoid distention of the proximal segment in end-to-end anastomosis. The latter do not seem to have tried what Lockwood and his associates recommend—before closing the abdomen, to milk the gut gently "from just above the distended area to just below the sutured area." Post-operative paralysis of the bowel and distention, they assert, "practically never occurred" when this simple precaution was taken.

Lacerated kidneys may recover if not too widely

injured. In these cases extensive experience and sound judgment are invaluable. Immediate nephrectomy is to be avoided, if possible, and to be resorted to (if then necessary) when the patient is in better condition.

Irrigation and drainage are not commonly employed. Fraser and Drummond, however, particularly urge drainage in wounds of the colon, and especially posterior drainage, to avoid retrocolic infection. Obvious infection elsewhere may also require drainage.

The Fowler position is desirable as soon as possible after the operation. If need be, drainage of the pelvis may be employed, but not probably for over twenty-four or thirty-six hours.

Sometimes morphin—which I have already commended as an initial measure for the relief of severe pain—is given in larger doses than is wise. This complicates recovery, especially by masking intra-abdominal symptoms.

According to Bowlby,* an operative recovery of 50 per cent. in present conditions is the best that one can expect—a great contrast to civil surgery! Hemorrhage is the principal cause of this deplorable result. Hence again the need for quick transportation and prompt operation except in such deep shock as to

* Brit. Med. Jour., June 2, 1917.

forbid operation until reaction has been attained. If salines are to be used, it should be by intravenous infusion, for in deep shock little if any absorption takes place if it be given subcutaneously. But if hemorrhage is the probable cause of the shock, then operation to control it is the only possible hope. The pulse is of the greatest importance. Of 145 cases with a pulse over 120, only 16 recovered—a mortality of over 89 per cent. After thirty-six hours operation is evidently unnecessary, as a rule.

Bowlby gives the following table of results in 1038 cases treated during eighteen months:

Considered with view to operation	1038	
No operation advised	73	
Total operations	965	
Total operative mortality	53.9	per cent.
Total hollow viscera mortality	64.7	"
Stomach mortality*	52.7	"
Small gut mortality*	65.8	"
Colon mortality*	58.7	"

* Uncomplicated by wound of other hollow alimentary viscus.

BURNS

These are much more frequent in this war than heretofore. Dr. Barthe de Sandfort greatly improved on the old paraffin dressings by a preparation which he named Ambrine, from the oil of amber mixed with the paraffin. I have seen a number of photographs of his cases, and have no doubt as to the value of the treatment. Unfortunately, in absolute contravention of American medical ethics, he has kept the exact formula and the method of preparing it secret, and it can be obtained only from him or from the commercial company in Paris to whom he has divulged the secret.

Lieut.-Col. A. J. Hull, of the British Army,* after a series of experiments, has obtained a preparation which experience has shown to be superior to Ambrine. He calls it "No. 7 Paraffin." The formula is as follows:

Resorcin	1	per cent.
Eucalyptus oil	2	"
Olive oil	5	"
Paraffin molle	25	"
Paraffin durum	67	"

* Brit. Med. Jour., January 13, 1917, p. 37.

The resorcin may be diminished to 25 per cent. If resorcin is difficult to obtain, the formula may be changed to the following:

Beta-naphthol	0.25 per cent.
Eucalyptus	2.00 "
Olive oil	5.00 "
Paraffin molle	25.00 "
Paraffin durum	67.75 "

The method of application is as follows: Wash the burn with sterile water. Dry it by fanning or by laying dry gauze on the surface. The paraffin mixture is then applied by a spray or by a broad camel's-hair brush, sterilized in wax and used very gently. This preparation has a melting-point of 48° C. (118.4° F.). It should be heated to 50° C. (122° F.), but this temperature can be roughly "estimated by waiting till the wax shows a solidifying film on the surface."

"A thin layer of cotton-wool, cut the same size as the area of the burn, is placed over the wound after the first layer of paraffin has been applied. This layer of wool is covered with a second layer of paraffin. The wool is cut in thin sheets and pressed between layers of paper in order to obtain thin layers of wool. The dressing is completed by applying wool bandage. The burns are usually dressed daily (or later every second day). . . .

"Blisters are not interfered with in any way at the first dressing; the paraffin is applied after washing the burn. At the second dressing the dead layers of skin are cut away."

This paraffin preparation has been employed to advantage also in "trench feet."

In the British Medical Journal of April 28, 1917, p. 549, is a further statement in reference to the paraffin treatment of burns. This shows also the atomizer which is used in spraying it over the wound.

In the Journal of the American Medical Association for May 19, 1917, pp. 1497–1500, is a very full explanation of the origin and composition of Ambrine and the various paraffin preparations by Paul N. Leech, Ph.D.

In the Journal of the American Medical Association for June 16, 1917, are two valuable articles by Sollmann and Beiter on the Paraffin Treatment of Burns which advance our knowledge considerably. Beiter especially has had a large experience in the treatment of burns in industrial works. Their conclusions are that the application of the ordinary melted paraffin to the wound is much too painful. They recommend, after cleansing, that the first application shall be the "Petrolatum Liquidum" (known commercially as "Stanolind Liquid Paraffin"), which can

be sprayed on the burn by the ordinary oil atomizer, or can be applied on a cotton swab. This is entirely painless. Then the cotton film is applied and the melted paraffin painted over it, etc., as usual.

Beiter says that "superficial burns heal more quickly by this treatment, but that when the tissues are destroyed in deep burns and scar tissue results, the scar tissue performs as scar tissue has performed since the beginning of time." Sir Anthony Bowlby, on the contrary, declares that the scars are "soft and supple and there is a marked absence of bad contractures." Others also have noted this advantage.

In the issue of the same journal for June 23, 1917, in order to melt and keep liquid the paraffin, Sollmann advises, when available, an electrical "food warmer," or better an ordinary glue-pot (size 0), containing something over a pound of sodium acetate. In this pot a smaller one, containing about a pound of paraffin, is placed. When the sodium acetate is melted at a temperature of 59° C. (138.2° F.) it will remain at an ideally usable temperature for two hours and be still usable for another hour. It can be reheated again and again.

SOME PERSONAL LETTERS*

Letter from Dr. Joseph A. Blake

Chief Surgeon of the Hospital V. R. 76, Ris-Orangis, France

November 22, 1916.

"I have received your letter of October 26th in which you request my views in regard to 'new discoveries and their application in the treatment of wounds in the present war.'

"It would require a book to reply satisfactorily to this question if all the methods of wound treatment were considered and recognition given to what their authors claim for them. I am not ready as yet to give a definite opinion in regard to any of them.

"In this hospital, with the help of Dr. Kenneth Taylor, the head of our Research Laboratory, I have been studying and making comparisons between several of these methods, and I am sending you a few reprints which may interest you. One is in connection with Sir Almroth Wright's method, which method, in our experience, is of no particular value.

* These letters from men actually in the war were written at m[illegible]st for incorporation in this Report.

"In regard to the Dakin solution and Dakin's chloramin-T, we are now trying to determine what the reactions in the wounds are of the hypochlorite solution. It is possible that an amin is formed in connection with the wound secretions. We are having good results with the Dakin fluid, using Carrel's method of instillation, but are having equally good results from other antiseptics employed in the same way. For instance, in cases of B. aërogenes capsulatus infections, we are using a solution of quinin, and in pyocyaneus infections we are using a weak solution of acetic acid or a combination of acetic acid and cresol, we having found that an acid solution is necessary to control the B. pyocyaneus. It grows freely in wounds treated with Dakin's solution.

"In general, I am inclined to believe that there is no antiseptic which fulfils all indications, and that the successful treatment of wounds depends largely upon the skill of the surgeon in preparing them for treatment and in dressing them afterward.

"In regard to the treatment of gas gangrene, I think the reprints which I am sending you will sufficiently explain the reasons for what I regard to be the best treatment, *i. e.*, free incisions through aponeuroses and fascia surrounding the muscles, and the separation of the muscles infected by blunt dissec-

tion with the fingers, the idea being to prevent the creation of subfascial pressure upon the muscles by contained gas and exudate.

. . . . . .

"I am sending you a reprint of a splint for transportation of fractures of the lower extremity.

"In regard to feeding, housing, etc., I can say nothing except that it should be the best obtainable. Of course, all this depends upon the facilities at hand and the rush of wounded. For instance, a hospital of 300 beds, in ordinary conditions of trench warfare, could easily find transport, food, and care for all the cases coming to it, but at any time might be swamped by a thousand cases in one day. . . . "

LETTER FROM SIR ANTHONY A. BOWLBY, BART.

General Headquarters, British Armies in France

[Penciled notes based on an enormous number of cases, written on foolscap, and evidently amid many difficulties.—W. W. K.]

"Until our Somme Battle quieted down I was living in a tent on the Ancre and not anxious to write more letters than I could help.

"I now send you some brief notes in reply to your inquiries. . . .

"We had a busy time, but we had anticipated and prepared for it, so all went very well and the wounded were all well looked after.

"I have been much struck by the excellence of very many *young* surgeons, for we have now at the front a really fine operating staff, and they have saved many thousands of lives by their skill and by very hard work. This has been a very encouraging feature amidst many sad sights, for the mutilations by shells are really horrible."

. . . . .

"*The treatment of wounds* which today finds most favor is that known as Carrel's. This may be briefly summarized as excision of any *recently* wounded or dirty tissue and the subsequent irrigation of the wound by frequent instillation of 'Dakin's fluid.' In the British army the preparation known as 'Eusol' is often used instead of Dakin's fluid, from which it does not materially differ.

"Wounds already suppurating are *not* treated by *excision.*

" 'Hypertonic Saline' [of Sir Almroth Wright] has been recently used very little at the front, as most surgeons consider that the hypochlorous acid solutions give better results. I hear that it is also not much used at the base hospitals, and personally, I have never seen any of the advantages claimed for it and have never advised its adoption.

"Various other antiseptics are used, such as car-

bolic acid, peroxid of hydrogen, etc., and a combination of the two named above finds favor with some surgeons.

"*Chloramin* has not been used enough yet to criticize. The *excision* of *damaged tissue* in all recently inflicted wounds is universally practised at the front whenever possible, *i. e.*, in all wounds of a serious or extensive nature.

"Fixation by efficient splints is always considered to be of very great importance.

"*Gas gangrene* may be caused by several different organisms and is commonly due to a 'mixed infection.'

"In a great majority of all lacerated wounds gas will develop if they are left long enough undressed; especially if the wounded man lies out for a day or two. It is best prevented by the treatment described above.

"In many cases it is slight and local, and easily checked by free incision and subsequent drainage. The affected muscle sheaths and fascia must be widely opened up, and if any one or two muscles are gangrenous, they must be excised.

"If a main artery is injured and the limb is affected by gas gangrene, amputation is necessary at once.

"In many compound fractures this same treatment is required.

"It is a noticeable fact that, however lacerated the face may be, gangrene never occurs in it or in the scalp, and hardly ever in the *neck*. I attribute this to the large blood-supply. I have never seen gas gangrene in any part of the *head*.

"*Gas* and gaseous crackling are often felt far above the area of *infection*, and it is a mistake to try and amputate above all *gas*.

"*Antitoxins* and *vaccines* have proved to be quite useless up to the present.

" 'Ambrine' is a very good application for burns or for the open sores (caused by frost or wet and cold) which occur in many cases of what we call 'trench feet.'

"It appears to be beneficial by reason of its physical properties, and not because of its chemical constitution. Its exact composition is not known.

"We use a similar preparation which we compound of (*a*) hard and (*b*) soft paraffin and (*c*) olive oil. The object is to get a soft, greasy preparation which can be taken off without injury to the raw surface and so without pain.

"The resulting scars are soft and supple, and there is a marked absence of bad contractures. Wounds also heal quickly.

"*Head Wounds at the Front.*—We avoid extensive operations and, with few exceptions, do not open an uninjured dura mater. It is very necessary not to move patients for about three weeks after operation, so that special accommodation is required.

"*Chest.*—Rest in bed and small doses of morphin for all and no tapping of effusion for several days.

"Subsequently, if there is a large hemothorax, either—(*a*) tap; (*b*) tap and replace with oxygen; or (*c*) if septic, excise rib and drain. Most cases can travel safely to the base after three or four days in bed, and operative treatment is generally done there."

[The general practice of experienced surgeons in France is along these conservative lines, I judge. Depage and Tuffier have also applied the Carrel-Dakin method in cases of empyema with much satisfaction. The various diverticula are traced by *x*-ray pictures of the chest by the introduction of the rubber tubes threaded with silver wire. When the discharge is sterile, the wound is closed.—W. W. K.]

"*Abdomen.*—Our general practice is *to operate* if the patient is got in before thirty-six hours, and very many are actually got in within three or four hours after the injury.

"Operations are *not* done if the wound is *high up* and there is good reason to believe there is no injury

to any *hollow* viscus, as evidenced by the absence of all symptoms and the site of the wound. (Of course, this statement might require revision in any *single* case, but it will give you an idea of our practice.)

"Our recovery rate for several thousand operations is about 45 per cent., mostly lives saved.

"*Place for Operations at the Front.*—At the *field ambulances* we only operate to—(*a*) Stop bleeding. (*b*) Amputate hopelessly smashed limbs. (*c*) Dress bad fractures, etc., under anesthetics. All other operations are done in the 'Casualty Clearing Stations,' of which there are over 50 spread behind our whole front and all accessible to road or rail. Patients can be kept in these in moderate numbers for a week or two, and can be got into them from the field ambulances in about half-hour to one hour.

"*Anesthetics.*—'Shipway's' apparatus for warm ether vapor is very good. It conserves ether, and there is a complete absence of all secretions of mucus and saliva."

LETTER FROM DR. HUGH CABOT

Boston

November 21, 1916.

" . . . It is not easy for me to say from anything more than hearsay evidence of conditions exist-

ing in previous wars, precisely what is new and what is old. Clearly the experience of the Russo-Japanese and Boer wars was grossly misleading in regard to methods of wound treatment. In those wars the majority of wounds were caused by rifle, machine-gun, and shrapnel bullets, and those wars were fought in a comparatively uncultivated region. As a result, many wounds were practically uninfected or only slightly infected. First-aid dressings promptly applied were of great value and conservative treatment gave good results.

"In this war a large proportion of the wounds are produced by fragments of the shell casing of high explosives. The wounds are lacerated, quantities of clothing are carried in, and as the soil is for the most part that of a highly fertilized region, infections with intestinal parasites, such as the Streptococcus fæcalis and the Bacillus aërogenes capsulatus of Welch, are practically universal. First-aid dressings have been of very little value, probably none beyond the exclusion of flies, thereby preventing the development of maggots in the wound where men lay out in shell-holes for two or three days. It has not been clear to me that the development of maggots was an important complication, and certainly no great enthusiasm can be evoked in regard to the value of

first-aid dressings. [During the Civil War I saw very many wounds swarming with maggots. They were very disgusting, but practically I do not think they did much harm. Cleanliness, disinfection, and protection of the wounds from flies by dressings will prevent their development.—W. W. K.]

"The experience of previous wars was also wholly misleading in regard to the treatment of abdominal wounds. The British surgeons, going upon their experience in South Africa, treated these cases conservatively during the first year, with a mortality rate that was nothing less than shocking. They, therefore, reversed their policy, established special hospitals as close to the firing line as possible, and have carried out a policy of operating upon all cases which could be brought to the hospital within eight hours after injury. The results in these cases have shown between 40 per cent. and 50 per cent. of recoveries—an enormous improvement over the previous policy.

"In regard to tetanus, it developed during the retreat of the early months of the war that wound infection with tetanus bacillus was almost the rule and the mortality was extremely high. Since that time prophylactic inoculation given by regimental medical officers as soon as casualties can be reached, in doses of from 250 to 750 units, has been brilliantly

successful. In the hospital area with which I was associated this summer between 25,000 and 35,000 casualties were received, and in this number there were only ten cases of tetanus, eight of which died and two recovered. My own experience in about 8000 casualties showed two cases, both of them developing in men who had lain out for more than two days in shell-holes, and whose inoculation was therefore delayed [and infection with the bacillus was unhindered.—W. W. K.]. One of them died promptly of acute tetanus; the other had the subacute type, coming on after about fourteen days, and should have recovered except for accidental complications. I think, therefore, we may regard the prophylactic inoculation of antitetanic serum as one of the great contributions to preventive medicine in war.

"The almost complete absence of typhoid fever must, I think, be attributed to vaccination, which is now done against three organisms—the typhoid bacillus, and the alpha and beta paratyphoid. The result has been the complete absence of typical typhoid. There are a moderate number of cases of unknown fevers of short duration which, on account of slight enlargement of the spleen and an occasional spot which might be a rose spot, must be classified as possible typhoid. Since all the men show a posi-

tive Widal reaction, diagnosis by this method is impossible except by methods altogether too laborious and time-consuming to be of practical value. The disease, whether or not it be typhoid, is trivial and has been a very unimportant factor in unfitting men for service. This, therefore, must also be regarded as a very important demonstration of the more or less generally accepted view that vaccination against these conditions, as at present carried out, is eminently successful.

"The ability shown by the Royal Army Medical Corps to prevent diarrheal diseases, commonly called dysentery, in the British Expeditionary Force in France, has been very striking. This, I take it, is the result of their conscientious supervision of water-supply and their ability to control the men. In contrast to this were the conditions existing in Gallipoli, where amebic dysentery was a very prevalent and serious cause of disability and death. Up to the time of my departure from France, about the middle of September, only a few cases of amebic dysentery had occurred and it had never been important.

"In regard to questions of transportation of wounded, the automobile ambulances have been used as never before and have been able to approach

the firing-line pretty closely. The number of casualties resulting from the shelling of ambulances appears to have been small, which, I take it, means that both sides have avoided this practice where possible. That it is not always possible results from the fact that the same road must be used for troops and for ambulances and that combatants are therefore justified in shelling the roads if they think it important in preventing the bringing up of reënforcements. The English have established a system by which all stretchers and all ambulance bodies are of a uniform type and are therefore interchangeable. For instance, in bringing a convoy to a casualty clearing station or to a semi-base hospital the stretchers on which the patients come are left at the hospital for the convenience of avoiding the shifting of patients, and other stretchers, precisely similar, with a full complement of blankets, are picked up by the ambulance as it leaves the reception tent.

"In regard to splints for the purpose of transportation, the extent to which the so-called Thomas knee-splint, with slight modifications to get better extension, has been applied to comminuted fractures, both of the leg and arm, is, I think, a distinct advance. It seemed to me altogether the most satisfactory splint for transportation purposes, and though giving some-

thing short of absolute fixation, it probably as nearly approaches this as is practically possible.

"Upon the question of the treatment of infected wounds, I am afraid that my observation will not enable me to indorse the very enthusiastic views expressed by some observers.

"Infection with the Bacillus aërogenes capsulatus of Welch, also called the Bacillus perfringens and the gas bacillus, is enormously prevalent. In my opinion, based upon cultures from some 200 consecutive cases, it is the active organism in over 80 per cent. My experience with this infection covers considerably over 5000 cases during three months, and I was enabled to see the results of Sir Almroth E. Wright's technic, since he was at work within fifteen or twenty miles of me. The essence of his theory depends upon the osmotic action of solutions of sodium chlorid of strengths up to 10 per cent., his thesis being that the stronger solutions stimulated serous discharge and tended to remove a condition which he describes as lymph-bound. I found that during the summer his views were undergoing considerable modification, that his dogmatism of June gave way to much greater catholicity in September, that he was using more and more the weaker solutions of salt and nearly approaching the use of a normal salt solution. As is

the case with Carrel and Depage, he has a well-equipped stationary hospital with a comparatively small number of patients and a large proportion of surgeons, and is, therefore, in a position to watch his wounds enormously more closely than can the ordinary field unit or even semi-base or base hospitals, and due allowance must be made for the very great care with which all these gentlemen supervise their treatment. I fear I must conclude in regard to Sir Almroth E. Wright's method that it depends more upon sound surgical principles and painstaking dressings than upon any peculiarities of solutions employed.

"I cannot speak from personal experience of Carrel's method, which, as you know, consists of pretty radical excision of damaged tissue, irrigation of the wound with a solution which does not importantly differ from Dakin's solution or eusol, a careful bacteriologic study of the wound, so that, at a comparatively early period,—from seven to ten days,—secondary suture can be successfully carried out. That the method as employed by him at his hospital has given remarkable results is undoubtedly true. On the other hand, it requires an amount of close personal supervision by skilled surgeons which is quite impossible under real war conditions. He is

not, in fact, doing military surgery, and one might, I think, properly say of the method, 'C'est magnifique mais ce n'est pas la guerre.' [Depage, with 800 beds, almost at the firing-line, I think has demonstrated that it is practicable.—W. W. K.] That Carrel's method may be of considerable service in civil practice seems to me fairly demonstrated.

"In regard to Dakin's solution, it has all the advantages of the old chlorinated soda, on which I was brought up and which has since largely disappeared. On this solution it is probably an improvement in that it is less irritating and quite as efficient. Its deodorizing properties are valuable, but I see no reason to believe that it has any power to penetrate into tissues not directly exposed, and as far as the infection with the gas bacillus is concerned, exposed tissues are comparatively easy to deal with. My own view of the treatment of these infections is as follows:

"Wounds must be laid widely open, and, as a rule, transverse rather than longitudinal incisions should be employed. That such incisions are not in fact more destructive than the longitudinal is due to the success achieved, as failure to control the infection results in a tissue destruction far more serious than that resulting from the incision. The projectile,

and particularly the clothing and foreign material carried in ahead of it, must be removed, and all pockets thoroughly laid open. The forms of dressing which tend to obstruct the wound must be avoided, particularly gauze packing. Flow of secretions must be promoted by keeping the wounds wet, and I do not believe that any one solution has demonstrated any clear superiority in this field. The use of multiple perforated tubes introduced into all portions of the wound, through which solutions can be introduced at frequent intervals, is clearly an advance in technic, but largely because it avoids frequent changes of dressing and favors the outflow of secretion. That Dakin's solution, eusol, eupad, etc., are popular, and that I myself prefer them, arises, I think, more from their deodorizing qualities than from any clearly demonstrated antiseptic action. On the other hand, I have a quite unconfirmable feeling that they probably have a definite value as antiseptics, and are probably superior to any other antiseptics with which I am familiar. Particularly under conditions of active fighting, where the number of surgeons is relatively small and frequent expert dressing difficult or impossible, salt solution, as recommended by Sir A. E. Wright, is likely to fail. Under the reverse conditions it is at its best. I have

seen a group of wounds treated with salt tablets or salt bags placed in the deeper portions of the wound, which is then kept wet with normal saline. While my experience is quite insufficient to form the basis of a scientific opinion, I have been impressed by the extreme cleanliness of these wounds and should not be surprised if it proved to be one of the discoveries of the war. . . . "

LETTER FROM DR. GEORGE W. CRILE

Professor of Surgery, Northwestern University, Cleveland, Ohio

November 4, 1916.

" . . . I would like to say, first, that the practice of giving large doses of morphin to a seriously injured man who is to be transported is of very great importance. It protects him against further shock and the effects of the loss of food and drink.

"I have not been able to form any conclusion as to the best method of treating gas gangrene, as all methods have proved so ineffectual. Of course, when it is to save the life of the patient, there is quick amputation, leaving the stump wide open, but this will lead to many needless amputations.

"I am satisfied that good results are being obtained by the use of Dakin's solution and by the use of Sir Almroth Wright's method. I have had a very con-

siderable amount of experience with Dakin's solution, and am convinced that it is superior to bichlorid or to any other antiseptic we have ever employed. I think this will bear thorough investigation. There are abroad at the present time some contradictory reports regarding this method. . . . "

LETTER FROM DR. HARVEY CUSHING

Professor of Surgery, Harvard Medical School, Boston, Mass.

October 28, 1916.

" . . . My own experience was largely limited to the treatment of cranial injuries, and it was not a particularly large one. I am sending you a reprint in which I have stated my feelings in the matter. . . . Although the metal helmets have lessened the number of small penetrating wounds which we saw, there are, nevertheless, of course, still a great number of them. One thing that will confront your committee, of course, is the question of protection, and it looks as though we were going back by gradations to the armor of the Middle Ages. Another very important thing is protection against gas attacks, and I am sorry you were not here Wednesday to hear Haldane speak on the subject, for gas masks of one type or another will unquestionably have to be [illegible]ed for.

"I hardly know what to say in answer to your questions in regard to the treatment of infection. Dakin's solution is being still used with apparently very good results, and the same is true of Wright's hypertonic saline. All these things, as is true of the treatment of wounds in general, come down to the basis, more or less, of a personal equation with the individual surgeon, and there has been a very extensive controversy, particularly in England, by those who regard themselves representatives of Lister, versus those who are opposed to the use of any antiseptics, and Wright is their very capable leader. . . . Carrel, as you know, is endeavoring to shorten the life of wound-healing by radical excisions of tissue after primary partial sterilization with Dakin's fluid.

"There seems to me no 'best treatment' for gas gangrene, for when gangrene has set in, it necessarily means amputation. I presume that your question really means gas infection, which is not such a dread condition as it was thought to be, and although amputations for gas infection were performed during the first part of the war, they very soon learned that gas infection, short of gas gangrene, was a very recoverable type of infection.

"Tetanus has absolutely disappeared, owing to the

immediate injections which are given at the first-aid stations, a very serious blow to the antivivisectionists. . . .

"Transportation you will find a very serious problem, particularly as our day coaches—unless holes can be cut in the sides—are absolutely unfit for the carrying of wounded, and the only cars which have side openings are freight cars, with impossible springs. . . . "

[As a commentary upon the above letters from Drs. Cabot and Cushing, I call attention to the following facts as to typhoid fever:

Mr. Forster, the Financial Secretary for War, in a speech in the House of Commons on March 1, 1917,* made this statement: "Nothing was more striking than the triumph of science over disease, wholly upsetting the experience of former wars. One of the most remarkable facts was the almost total disappearance of enteric fever." He then went on to point out that in spite of the "vast numbers of the army, their density on the ground and conditions of the soil in France, the last weekly returns of the numbers of typhoid patients were as follows: In France there were 4 cases; in Salonica, 9; Egypt, 3; Mesopotamia, 8—a total of 24.

* Brit. Med. Jour., March 10, 1917, p. 340.

"The total number of cases of typhoid fever in British troops in France down to November 1, 1916, was 1684; of paratyphoid, 2534, and of indefinite causes, 353, making a total of 4571 of the typhoid group."

[In our own Spanish-American War in 1898 *every fifth man* contracted typhoid fever. If the same ratio (1:5) had held in the British army alone in the present war, there would have been about 1,000,000 cases. *The actual number has been less than one case in every 1000 men, instead of one in every five men.* In the German army also typhoid has practically disappeared.]

Mr. Forster called attention to the enormous change since the Boer War, when, in their relatively small army, there were 60,000 cases and over 8000 deaths. He also made the following statement: "The admission ratio of typhoid fever amongst the troops in France who had not been protected by [typhoid] inoculation was *fifteen times* higher than among those who had been inoculated, and the death rate was *seventy times* higher."—W. W. K.]

LETTER FROM DR. CHARLES L. GIBSON

Adjunct Professor of Surgery, Cornell University Medical School, New York City

November 10, 1916.

" . . . The inclosed is a dictation I made from memory of the remarks that I made at a recent meeting of the Society of Clinical Surgery. . . .

"Depage showed me several cases of gas gangrene which he had treated by injection of oxygen under feeble pressure with most excellent results and marked diminution in the mortality. The area affected is penetrated in many places by a needle by which the oxygen is introduced, and it is sought to have the evidence of the penetration of the oxygen by its appearance in the wound. . . .

"On arriving at Paris the first week in July I found awaiting me a letter from Carrel saying that he had some interesting things to show me in his work on infection, and that by the process that he was now using suppuration was practically eliminated. I did not go to Compiègne for some days, and found that opinions were divided in Paris as to the value of the method. A small but enthusiastic majority, which I subsequently joined, were very much impressed with the results and the method. This party was composed exclusively of persons who had

taken the trouble to go to Compiègne or to Depage at La Panne and see for themselves the method as it was done there and done rightly. Subsequent observation on my part and the testimony of Carrel showed that there were very few institutions outside of Carrel's hospital where the method was understood and practised right, and consequently good results obtained. Much misconception exists about the method, and I confess that until I went to Compiègne I had no conception what it meant.

"When the method was first brought out, its possibilities were probably exaggerated and some false hopes were raised that by its use the tissues could be so efficiently sterilized that less energetic surgical methods would be needed. Such an impression got abroad, and when it was finally seen and realized that neither this method nor any other method could take the place of sound surgical treatment,—removal of infection (foreign bodies), free drainage, surgical cleansing, etc.,—there came a reaction in some quarters against the method, and a prejudice was started which it has been difficult to dispel even by the proven success of the every-day method. . . .

"These wounds [*i. e.*, those treated by the Carrel-Dakin method] heal in a manner that is simply indescribable. One has to see the behavior of these

sutured wounds oneself to realize what happens. They heal with no more reaction from their appearance and manifestations than would be given by a wound which has been sutured on a cadaver—total absence of reaction, pain, swelling, redness, and even of infiltration around the wound-edges. Dr. Dehelly, of Havre, tells me that he has closed 400 of these wounds, with only six failures to obtain perfect primary union. Of these six mishaps, none were of any importance, and in some of these Dehelly said the fault was probably due to his failure to await complete sterilization, as evidenced by the bacterial count.

"Carrel realizes that the method requires a good deal of care and personal attention, and is seeking to modify it by having an antiseptic which may be readily and continuously diffused all over the wound surface. He would like to use it very much as one does Beck's paste, which permeates every nook and cranny of a given cavity. For superficial surfaces he is using a chloramin ointment. So far he has not been able to find a suitable medium to introduce into the deep wounds. He feels now that the question of sterilizing perfectly fresh wounds has been solved, and on my second visit to him, nearly two months later, I found he was just beginning to try it out in

old infections. He had just received a batch of 'neglected' cases who had been through a number of hospitals, and some had not had their dressings changed in ten days. Miss R., a nurse whom I sent to study the method at Carrel's, is just back, and tells me that his success in handling these old infections is apparently going to be as great as in the fresh. I talked over with him the possibility of utilizing this form of applying an antiseptic to other forms of infection, and he believed that there would be a future for it.

"My next experience with the application of the Carrel method was at the hospital of Dr. Depage, at La Panne, Belgium. He has a wonderfully well-equipped hospital of 800 beds, with everything to work with, and, in fact, six miles from the firing-line he has a better equipped hospital than many an institution in New York city. He is a firm believer in the Carrel method, because he took the trouble not only to send his assistants to become familiar with it, but studied it himself at Compiègne. He has established it on a large scale, and is extraordinarily satisfied with its results. For example, he made the statement that he had 80 compound fractures in one ward and not one was suppurating. I was given an opportunity of seeing the dressings in this ward, and in

these 80 cases I can verify the statement of Dr. Depage in that I did not see one single drop of pus."

LETTER FROM DR. HENRY H. M. LYLE

Professor of Clinical Surgery, Columbia University, New York

January 20, 1917.

" . . . At the front there are at least four different methods of treating shell wounds:

"1. The common or open treatment, by incision, drainage, and the use of different antiseptics, balsams, etc., as carried out in civil life.

"2. The so-called physiologic or hypertonic saline treatment of wounds, as advocated by Wright.

"3. The Carrel method.

"4. The treatment of wounds by the method of excision.

"In my limited experience the last two methods give far superior results if carried out thoroughly. Of the two, the Carrel method is the safer and has the wider application. However, the fourth method, in the hands of experienced and trained men, gives the most brilliant results, and this often in places where you would least expect, as, for example, in the joints. The method calls for good judgment, the early reception of the patient, and the retention of the patient under the care of the operator for a long

enough period to insure that the wound is progressing favorably. If, under this method, an infection should occur, the Carrel treatment should be instituted at once. I was very much interested to note that this method was successfully carried out by Baron Larrey in the Napoleonic wars. In reading his 'Mémoires,' I notice he gives the credit of originating this method to Desault. The great possibility of danger in the careless application of this method has kept me from writing on this subject, but personally I feel that in properly selected cases, and carried out thoroughly, it gives the best results of any of the methods.

"In all the above methods, whatever the after-treatment, the immediate extraction of the projectiles, clothes, etc., is the practice in the best front line ambulances.

"The French dressings used in the front line ambulances, and their method of applying and removing them, are superior in safety, speed, and simplicity to those in vogue in our civil hospitals."

The Treatment of Gunshot Wounds*

By Sir Berkeley Moynihan

The problem of the treatment of gunshot wounds has been profoundly modified, if, indeed, it has not been radically altered, by the knowledge gained during the present war. Neither the civil experience of the last forty years, nor any recent military experience, had prepared us for the kind of work which, from the very outbreak of the campaign, it was our duty, as surgeons, to perform. The new and unexpected things which occurred were due to a set of circumstances each one of which was in some degree different from anything we had observed before. The character of the missiles in respect to the mode of flight and velocity was not that with which former wars had made us familiar. The damage inflicted upon the tissues was far greater than, and different in quality from, that commonly seen in South Africa; the organisms carried into the wound from the surface of the body, from the earth around, or by fragments of clothing, judged by their clinical results, transcend in virulence or in fecundity anything known by the present generation of surgeons; and, finally,

* Brit. Med. Jour., March 4, 1916, p. 333. (Résumé by Dr. Keen.)

the soldier, in the earlier months of the war at least, had undergone so serious and prolonged a strain, before being wounded, that he often fell an easy victim to a bacterial onslaught of great ferocity. . . .

Lister clearly distinguished the difference between the prophylactic and the therapeutic value of antiseptics; he emphasized the great importance of the former, and pointed out the inadequacy of the latter. The work of surgeons, since Lister taught, has depended for its almost incredible success upon the prevention of infection in wounds deliberately inflicted—not upon the control of an infection already established.

Letter from Dr. Fred. T. Murphy

Professor of Surgery, Washington University Medical School, St. Louis, Mo.

December 29, 1916.

" . . . Conditions vary so on the Continent, as well as the character of the material, that any expression of opinion as to treatment must be recognized as only a personal opinion. I was very much impressed by—

"1. The use of antitetanic serum.

"2. The great importance of the period of time elapsing between the receipt of the wound and the establishment of final surgical treatment.

"3. The application of the various types of fixation apparatus.

"4. The use of special solutions for irrigation.

"5. The coöperation between the dentist and surgeon.

"6. The necessity of the preservation of all loose spicules of bone in compound fractures.

"To comment very briefly upon these impressions: The system of giving antitetanic serum has been so perfected that practically every wounded man receives his injection within the first few hours after the injury. Cases of tetanus were practically never seen in Paris. Now and again an atypical late case has been observed.

"In comparing the wards at Compiègne and La Panne, where the wounded were received within the first two to six hours after injury, with those at Paris, where they were received days and weeks after they had been wounded, it was difficult to believe that the wounds in both places had been originally of the same character.

"In the use of plaster with the supporting metal strips for fixation of the extremities in transit it seems to me that a distinct contribution has been made to surgical equipment. This plaster was applied next to the skin, and the fixation was such that

the tissues were not further lacerated, the patient was made comfortable, and there was ample opportunity for any dressings that might be needed. The balanced splints swinging from an overhead support which have come into such general use in the hospitals seem to me also to be a very valuable addition to our surgical apparatus. By these splints the patients were made very comfortable; they were allowed a freedom of motion that would have been impossible with any other type of apparatus; and yet extension and fixation could be maintained perfectly satisfactorily. Also it was possible to carry out irrigation and to do dressings in a way which would have been impossible with the older type of support.

"One saw many solutions used for irrigation. That of Carrel, the so-called Dakin's, seemed to me to be the only one which had given such results as to warrant any very special consideration. I could not see that solutions of quinin or dilute alcohol or iodin were to be preferred to salt solution. Such conservative observers as Tuffier and Depage thought very highly of the Dakin solution for irrigation. Certainly at Compiègne and La Panne the wounds were in very good condition. I, personally, feel that the detail with which the treatment was carried out by

Carrel and the type of the cases under treatment had very possibly a very material effect on these results.

"By the coöperation between the dentists and surgeons results were and are being obtained which are nothing short of miraculous. To turn these extensive jaw injuries over to the dentist without surgical supervision would, I am sure, be a mistake, but by the application of proper prosthetic appliances, bone fragments are preserved and contractures are prevented, so that the surgeon has a bony framework over which to apply the plastic which would be to a large extent lacking without this preliminary treatment.

"At the ambulance we had the opportunity to compare cases from two hospitals near the line at which entirely different ideas were carried out in treating the compound fractures. In the one, all loose fragments were removed and the ends smoothed off. In the other, practically nothing was done but to insert drainage-tubes into the lacerated mass. The difference seen between the results of treatment was most startling. After removal of the loose fragments of bone, union was delayed and prevented in many cases, and by the resection of the ends of the shattered bones flail extremities were left which were practically useless. On the other hand, in the cases

based on ultra-conservative treatment the results were practically uniformly satisfactory. Provided the spicules were not removed, there seemed to be almost no limit to the amount of shattering which might be followed by a complete reëstablishment of the shaft.

"From the work of Taylor, and from the large clinical experience of the men with gas gangrene, it seemed to me that the treatment had been reduced to very simple essentials; that is, the removal of non-viable muscle and sufficiently free incisions so that muscle could not be further strangulated under the fascial planes from the tension following the gas production. As soon as dead muscle is removed as a culture-medium, the activity of the Bacillus aërogenes is very sharply limited. Personally, I was not favorably impressed by the use of oxygen injected into the tissues. It seemed to me that the trauma of this injection did more harm than good.

"We had no opportunity at Paris to see the number of cases treated by Sir Almroth Wright's method. I should judge, from the personal reports which I heard from men who had seen the method used at the English bases, that the results had not been very satisfactory."

APPENDIX

Adhesive Plaster for Extension in Fractures

From the British Medical Journal of July 14, 1917, p. 60, I append what is apparently a useful means for applying extension in fractures, especially of the lower extremity:

"Last August we published a note on a method of fixing extension to fractured limbs by the use of a glue adhesive, introduced by Major M. Sinclair, R.A.M.C., for use especially in the application of the extension to compound fractures of the lower limb. As we have received inquiries with regard to this, we have obtained information as to the formula at present used and the method of application. The formula in general use is as follows:

Ordinary glue	50 parts
Water	50 "
Glycerin	2 "
Calcium chlorid	2 "
Thymol	1 part

"The glycerin and calcium chlorid are both deliquescent and take up the perspiration, which keeps the glue from getting brittle, and, more important still, allows perspiration to take place. This prevents the skin from getting sodden, in which condi-

tion bacteria may flourish and give rise to skin troubles. The thymol is added to prevent putrefaction and diminish smell. Every time the adhesive is heated the odour gets less and less. Experiments have proved that bacteria do not grow on this preparation. Air-tight tins which hold about a pound are filled and sterilized at 100° and placed in store. When required, the contents are melted in a water-bath, and set aside a few minutes to cool.

"The adhesive is applied with the palm of the hand or a brush. The skin is washed with soap and sodium carbonate solution (four drachms to the pint) in order to remove fat, and when dry the adhesive is applied *without* shaving the part. The area is covered evenly, and the ordinary four-ply gauze as it comes out of the packet applied, having roughly measured the requirements and gathered it in at the level of the wrist or ankle. An alternative method is to put on a length of 'Elastic cotton net bandage' (S. Maw) from knee to ankle, to glue it on the *outside*, and then to apply the gauze as above and bandage carefully with a thin bandage.

"The gauze, being spread out fan-shaped, adapts itself to the conformity of the limb, and is kept in apposition with the skin by a loose woven bandage. The extension can be made almost immediately.

"The above method of extension is a very great saving of time, and, when compared with the cost of good strapping, is as sixpence to three shillings a limb. The following slight modification in the for-

"3. The application of the various types of fixation apparatus.

"4. The use of special solutions for irrigation.

"5. The coöperation between the dentist and surgeon.

"6. The necessity of the preservation of all loose spicules of bone in compound fractures.

"To comment very briefly upon these impressions: The system of giving antitetanic serum has been so perfected that practically every wounded man receives his injection within the first few hours after the injury. Cases of tetanus were practically never seen in Paris. Now and again an atypical late case has been observed.

"In comparing the wards at Compiègne and La Panne, where the wounded were received within the first two to six hours after injury, with those at Paris, where they were received days and weeks after they had been wounded, it was difficult to believe that the wounds in both places had been originally of the same character.

"In the use of plaster with the supporting metal strips for fixation of the extremities in transit it seems to me that a distinct contribution has been made to surgical equipment. This plaster was applied next to the skin, and the fixation was such that

then failed to kill the organisms exerts subsequently little or no inhibitory effect on the proliferation of the survivors. On the other hand, concentrations of the flavines, which at this period have merely inhibited multiplication, later on prove bactericidal, so that finally the flavine compound is ten to twenty times more lethal than corrosive sublimate."

Hence, instead of renewing the solutions every two hours, only one or two daily dressings are required.

Third.—They are apparently harmless to the tissues. "Experiments show that such concentrations of flavine, while effectively controlling the bacteria, do not interfere with phagocytosis."

Brilliant Green.—Brilliant green, like the hypochlorites, in the presence of serum soon loses its value as a bactericide; hence if used, it must be renewed at frequent intervals. But, on the other hand, "it possesses the advantage of being an extremely potent bactericide,—far exceeding the flavines in watery solution,—while at the same time it is comparatively harmless to phagocytosis, as well as to the tissues locally, and when applied to a wound, it is devoid of general toxic action on the body." Its use by Lt.-Col. Hull, of the British Army, by two-hourly flushings after Carrel's method, has proved most encouraging.

In *burns* also irrigation of brilliant green, followed by paraffin treatment, Col. Hull has found superior to any other treatment.

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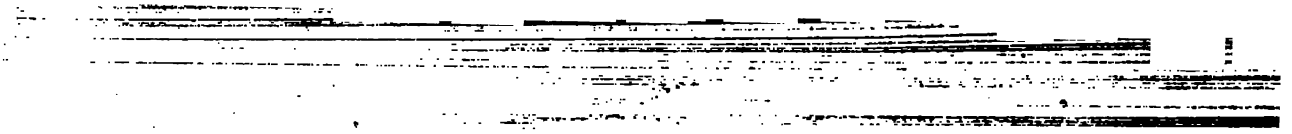

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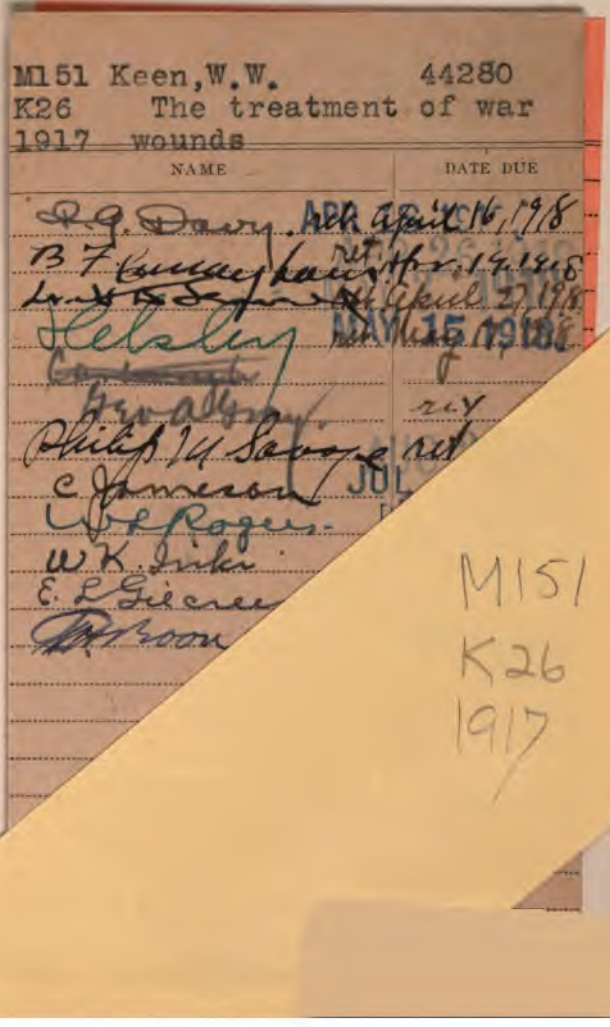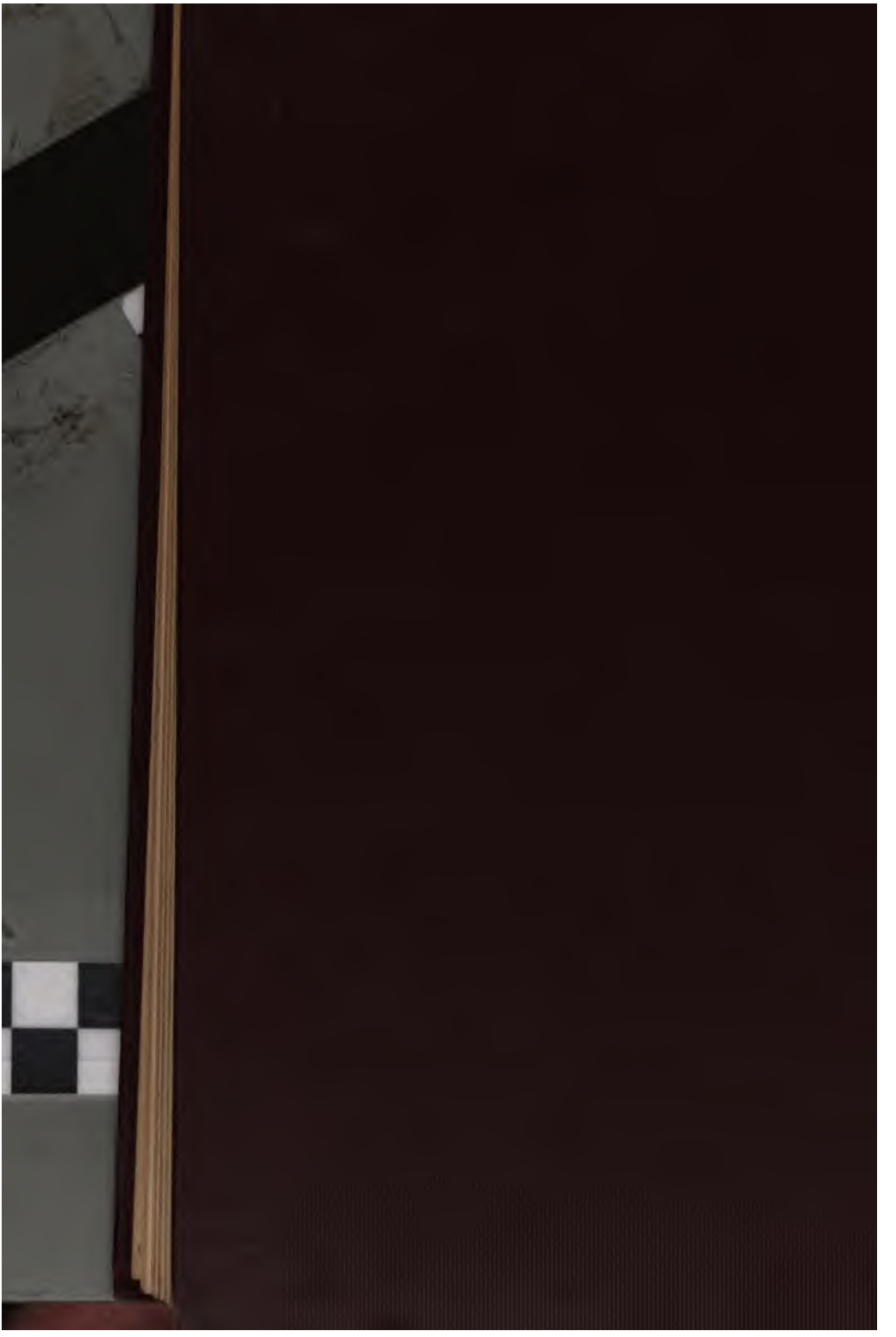
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